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FERTILIZER TRIALS ON PEASANT FARMS IN GHANA

D. STEPHENS

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Summary

Following experiments with fertilizers on agricultural stations, nearly 1,200 small trials have been carried out on peasant food farms to confirm the major nutrient deficiencies of the different areas and determine the economic uses of fertilizers under present conditions in Ghana. The results of these trials are described and fertilizer recommendations for the chief food crops in different areas are made.

FERTILIZER trials on land cropped and cultivated by the native farmer according to his normal practice were first carried out in Ghana by Nye, who has described the aims, methods, and results of his experiments [1]. Similar trials have been continued and have led to definite recommendations for the use of fertilizers by the ordinary small farmer growing food crops; the results of all these trials completed before 1957 are presented in this paper, which is intended to bring the previous publication up to date.

In brief, the practice in these trials was that the plots were laid out, fertilizers applied, and harvest yields, &c., recorded by employees of the Department of Agriculture, whilst the farmer supplied and sowed the seed and cultivated the crop in his normal way. The main purpose was to test on ordinary farms for a number of years those fertilizers which had shown promise in experiments on agricultural stations and to determine their most economic uses under present conditions.

The areas and crops investigated have remained very similar to those originally surveyed and described by Nye [1]; all places named in the text are shown in the sketch map (Fig. 1), which also outlines the main vegetational [2] and geological divisions [3] of the country. The most common layout was a 3^2 NP factorial design consisting of nine $\frac{1}{40}$-acre plots, in which all combinations of the following treatments were tested:

N at 0, 60, and 120 lb. ammonium sulphate (21% N).*

P at 0, 60, and 120 lb. single superphosphate (18% P_2O_5) (since 1952 the granular form has been used).

Other types of trial which were also used are described later.

Groundnuts in the Northern Savannah

Four different types of trial have been used: (*a*) in 1950, three-plot trials, with 0, 60, and 120 lb. single superphosphate; (*b*) in 1951 and 1952, two plots with 0 and 120 lb. single superphosphate; (*c*) in 1955, three plots with no fertilizer, 120 lb. single superphosphate (21·6 lb. P_2O_5) and 50 lb. triple superphosphate (20 lb. P_2O_5) (if the more concentrated form were equally as effective it would, because of lower transport costs,

* All rates of application (and yields) are per acre throughout.

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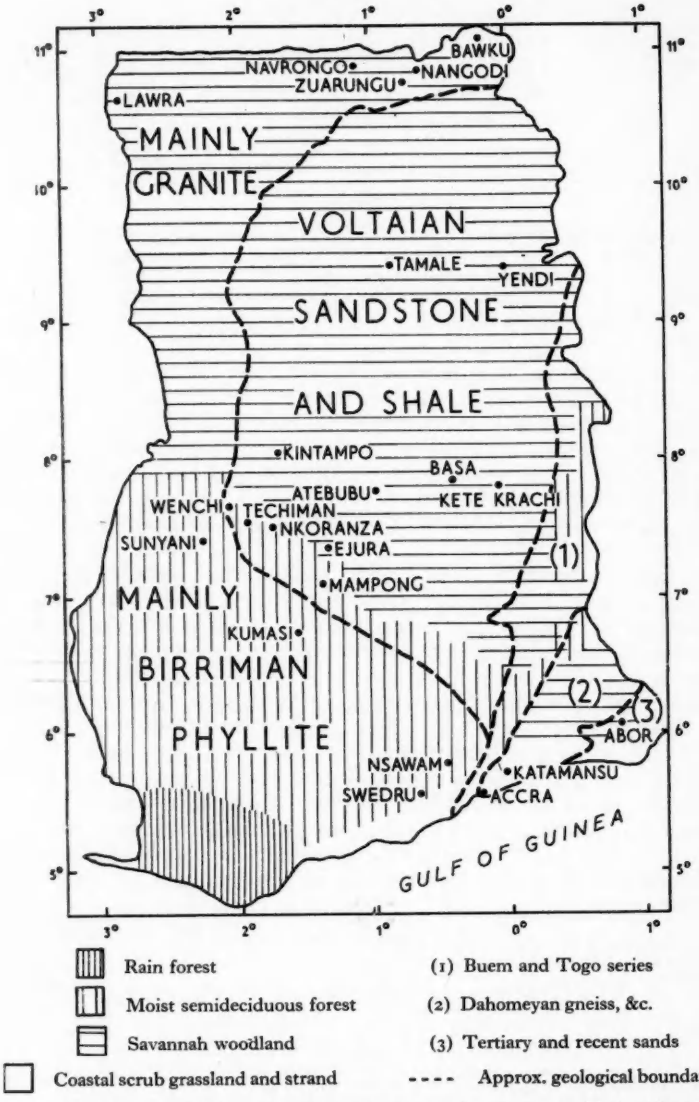

FIG. 1. Sketch map of Ghana showing trial areas and main vegetational and geological zones

be cheaper than the equivalent amount of the single form); (*d*) in 1956, four plots with 80 lb. gypsum, 120 lb. single super, 50 lb. triple super, and a mixture of 80 lb. gypsum + 50 lb. triple super—the aim being to evaluate the importance of the gypsum content of single superphosphate.

The fertilizer was usually placed in a ring around each plant 1 or 2 weeks after emergence, but sometimes it was broadcast before planting; the former method was favoured primarily because it prevented materials and effort from being wasted on farmers who failed to keep their promises to plant.

The effects of superphosphate are summarized in Table 1: groundnut yields were always significantly increased by 120 lb. single superphosphate. In the far northern districts around Lawra, Navrongo, Zuarungu, and Bawku, where groundnuts are most important and are mainly grown on coarse sandy soils derived from granite, the average response to 120 lb. single superphosphate was 324 lb. shelled nuts (kernels); around Tamale and at Nangodi, which has stony clay soils formed from Upper Birrimian greenstone, the trials were fewer and the responses rather smaller. At all localities except Navrongo the response to 60 lb. single superphosphate was more than half that to 120 lb., the mean ratio for the four granite areas being 0·64.

Using the above-quoted figures for the far north and taking the average prices of groundnut kernels and single superphosphate in these areas to be 45*s*. and 35*s*. per cwt. respectively, then if the responses obey the Mitscherlich equation the optimum rate of single superphosphate would be 185 lb., which would increase kernel yields by 396 lb. and give a net profit of £5. 1*s*. 0*d*. per acre exclusive of the residual effects of the fertilizer. Using only 120 lb. of fertilizer the net profit would be £4. 12*s*. 0*d*.; it seems, therefore, that the rate is not critical; furthermore, the lower rate of about 1 cwt. single superphosphate may be more convenient to the farmer since it requires less capital outlay and a little less labour to apply. In this part of Ghana, then, single superphosphate can be very profitable on groundnuts and, taken in conjunction with the use of improved varieties and close spacing to control rosette disease, it should be possible to double or treble farmers' yields unless marketing conditions and price fluctuations are unfavourable.

Table 1 also shows that in the far north 50 lb. triple superphosphate (20 lb. P_2O_5) was significantly less effective than 120 lb. single super (21·6 lb. P_2O_5). Results obtained by Greenwood [4] and others under comparable conditions in Northern Nigeria suggested that the special effectiveness of single superphosphate was due to its gypsum content. This view is supported by the yields in the 1956 trials (Table 2); there was no significant difference between single superphosphate and an equivalent mixture of triple superphosphate+gypsum, while both these treatments outyielded triple super or gypsum alone. It is interesting to note that in experiments on agricultural stations in the area, triple superphosphate was found to be at least as effective as single, and it was indeed because of this that triple superphosphate was tested in the trials on native farms. The explanation for the apparent contradiction between the two groups of results is probably to be found in the fact that the station sites had periodically received kraal manure (at the rate of 2–4 tons every third year), the residues of which might supply sufficient sulphur for the groundnut experiments, whereas the native groundnut farms had rarely been manured.

TABLE 1. *Effects of Superphosphates on Groundnut Kernel Yields*

P_2 = *Effect of 120 lb. single superphosphate per acre*

Locality	*No. of years*	*No. of trials*	*Mean yields of kernels in lb./acre*			*Mean effects of other treatments as fractions of* P_2			
						60 lb./acre single super		*50 lb./acre triple super*	
			Without phosphate	*With 120 lb./acre single super*	*L.S.D. ($P = 0.05$)*	*No. of trials*	*Effects*	*No. of trials*	*Effects*
Tamale . .	1	24	431	633	111	24	0·50	..	..
Nangodi . .	1	3	612	833	..	3	0·54	..	..
Lawra . .	3	55	557	872	60	14	0·70	20	0·58
Navrongo . .	3	71	527	915	62	27	0·43	28	0·58
Zuarungu . .	2	26	473	783	85	17	0·67	..	..
Bawku . .	3	92	372	652	44	22	0·75	40	0·58
Mean for far North excluding Nangodi . .	244		482	806	31	80	0·64	88	0·58

TABLE 2. *Groundnut Yields with Superphosphate and Gypsum*

Locality	*No. of trials*	*Gypsum (19 lb. S per acre)*	*Mean yields of kernels in lb./acre*			
			Triple super (20 lb. P_2O_5 per acre)	*Triple super + Gypsum (20 lb. P_2O_5 + 19 lb. S)*	*Single super (21 lb. P_2O_5 + 17 lb. S)*	*L.S.D. ($P = 0.05$)*
Far north (Lawra, Navrongo, and Bawku areas).	53	660	748	821	866	55

Nye has mentioned [1] that yields on the manured farms were higher than on the unmanured and that this seemed primarily due to the phosphorus content of the manure; nevertheless his results showed that responses to superphosphate were approximately the same on both types of site, and he suggested the likely explanation that the manure not only supplied phosphorus but also raised general fertility so that the crops could respond better to the extra phosphorus from the fertilizer. These findings are supported by the group of Lawra 1952 trials, which was the only one of the later series to include a number of sites known to have been manured at least once during the preceding three years. Here the mean yields without superphosphate were 952 lb. on the manured and 602 lb. on the unmanured sites; whilst responses to 120 lb. single superphosphate were almost identical, being 211 lb. on the manured and 224 lb. on the unmanured sites.

Thirty-seven calculations were made to test the significance of the correlations of mean yields and treatment responses with: (i) the number of years since the last fallow; (ii) the available soil phosphorus as determined by Bray's method for acid soluble+adsorbed phosphate [5]; and (iii) the time of applying the fertilizers. Only one significant correlation was found: at Navrongo in 1956 the mean yield (y) was highly significantly correlated with the number of preceding years of cropping (x), the regression equation being $y = 36x+140$; this means that yields were higher the longer the land had been cropped, a surprising result which suggests that occasional applications of kraal manure to the more permanently cultivated land are more effective than short periods of natural grass fallow in improving soil fertility. In general it would appear that, in the far north, a bush fallow does little if anything to raise the fertility of the land, Bray's test cannot forecast the level of the phosphate response, and the time of application of superphosphate is not critical.

Millet and Guineacorn in the Northern Savannah

The standard 3^2 NP factorial design was used in 1950 when most of the trials were carried out as already reported by Nye [1]. In 1956 the two series of trials around Navrongo and Bawku each consisted of 20 four-plot trials with the treatments: (i) no fertilizer; (ii) 120 lb. ammonium sulphate with half applied to early millet a few weeks after germination, and the rest applied to the guineacorn after the millet harvest; (iii) 120 lb. single superphosphate applied to both crops a few weeks after germination; and (iv) both ammonium sulphate and superphosphate treatments together. Most of the trials were on early millet and guineacorn mixtures; but some of the 1950 crops were early millet and late millet, or millet or guineacorn separately.

Yields and responses averaged over all types of cereals are summarized for each locality in Table 3. Everywhere the superphosphate had a greater effect than the ammonium sulphate. If we assume cereal grains to sell at 25*s*. per cwt. and apply the Mitscherlich equation to the mean figures for the far north (excluding the Nangodi greenstone sites), we find that the optimum rate of single superphosphate was about 1 cwt. per acre, giving a yield increase of 245 lb. grain and a net profit of £1 in the

TABLE 3. *Effects of Ammonium Sulphate and Single Superphosphate on Millet and Guineacorn Yields*

N_1 = Effect of 60 lb. ammonium sulphate per acre; P_1 = Effect of 60 lb. single superphosphate per acre.
N_2 = Effect of 120 lb. ammonium sulphate per acre; P_2 = Effect of 120 lb. single superphosphate per acre.

Locality	*No. of years*	*No. of trials*	*Mean yield in lb. grain/acre*	*Mean effects of 120 lb. rates in lb./acre*			*Effects of lower rates as fraction of that of 120 lb. rate*				*Interaction N_2P_2 as fraction of mean yield*	
							N_1		P_1			
				N_2	P_2	*L.S.D.* ($P = 0{\cdot}05$)	*No. of trials*	*Effects*	*No. of trials*	*Effects*	*No. of trials*	*Effects*
Nangodi .	1	11	1,451	294	588	90	11	0·43	11	0·31	11	0·04
Lawra .	1	22	390	50	141	70	22	0·46	22	0·76	..	..
Navrongo .	2	73	913	232	322	46	56	0·58	56	0·67	17	−0·01
Zuarungu .	1	31	1,107	260	363	60	31	0·96	31	0·63	..	..
Bawku .	2	61	986	115	239	62	41	0·62	41	0·43	20	−0·03
Mean for far north excluding Nangodi		187	849	114	266	30	150	0·65	150	0·62	37	−0·02

year of application; the residual effects of superphosphate would give additional profit if the land was cropped in succeeding years. Ammonium sulphate, costing nearly 50*s*. per cwt. in these areas, would not be economic even though the guineacorn on many farms later in the season looks as if it were suffering badly from nitrogen starvation. The interaction between responses with ammonium sulphate and with superphosphate did not approach significance.

In the 1956 trials the mean yields on sites which had groundnuts in 1955 were about 21 per cent. higher than where cereals had been grown. In the groundnut trials, described earlier in this paper, although no balanced comparison of the effects of different preceding crops can be made, the yields from both no-fertilizer and superphosphate-treated plots were from 1 to 25 per cent. higher after cereals than after legumes. Neither of these effects is statistically significant; but they support the view, for which there is independent evidence, that cereals do better when they follow legumes and groundnuts do better after cereals.

Yams in the Voltaian Savannah

Between 1950 and 1956 the Ejura-Atebubu, Wenchi, Tamale, and Yendi areas were covered by the standard 3^2 NP trials. Superphosphate was, however, omitted from the trials carried out in the important yam-growing area centred on Basa during 1954 and 1955, when each trial had four plots, each of twenty-four mounds (approximately $\frac{1}{40}$ acre), with the treatments: (i) no fertilizer; (ii) one early application of 80 lb. ammonium sulphate in May after the yams had sprouted; (iii) one late application of 80 lb. sulphate of ammonia (in 1954 during September–October, about a month after the start of the second rains; and in 1955 in August, at the end of the first rains); and (iv) a combination of (ii) and (iii) (i.e. early *and* late dressings).

In all these trials the yams were planted in mounds, spaced at from 4 to 10 feet, generally rather wider apart in the Ejura-Atebubu and Basa localities than around Tamale or Wenchi; often other crops, such as maize, rice, millet, groundnuts, calabash, peppers, beans, or other vegetables, were planted between or on the sides of the mounds. Staking and capping were everywhere recognized as beneficial and commonly practised. In the Basa and Ejura-Atebubu areas the yams nearly always followed directly after at least 2 to 4 years bush fallow and usually much more, the normal rotations being bush fallow, yams, rice, groundnuts (often omitted) around Basa, and bush fallow, yams for 1 to 3 years, groundnuts+maize, rice in the Ejura-Atebubu area; but one-quarter of the sites in Wenchi district and three-quarters of those around Tamale had been cropped for the preceding 1 to 5 years. Each district has a number of local varieties of yam but, with few exceptions (e.g. water yams on some Wenchi sites), those used in the trials were white types.

Apart from the late applications in the Basa 1954 and 1955 series, the fertilizers were applied between April and June, after the yams had sprouted with the first rains, 1 to 5 months after planting; a rough ledge

was made around the mound 6–12 inches from the top; the fertilizer was sprinkled on the ledge and covered with soil.

From Table 4 it will be seen that the responses to ammonium sulphate were large around Ejura and Atebubu and fairly good in Wenchi district, whereas superphosphate was ineffective in these areas. On the more frequently cropped farms of Tamale and Yendi the responses to superphosphate and to ammonium sulphate were more nearly equal, both being quite large. These facts bear out Nye's finding [1] that long fallows in the savannah region produce soils very short of available nitrogen and reasonably supplied with phosphate, whereas more frequently cropped land is less deficient in nitrogen but lacking in phosphate. The ratio of the effects of the lower and higher rates of ammonium sulphate was 1 : 3 for Ejura-Atebubu, 2 : 3 for Wenchi, and 3 : 4 for Tamale (conforming with the pattern of increasing nitrogen shortage with longer fallows). The higher rate of superphosphate was everywhere more than twice as good as the lower rate. The interaction (NP) between superphosphate and ammonium sulphate was nowhere significant.

Correlations of mean yields and fertilizer responses with (i) plant population, (ii) site history, (iii) time of application of fertilizers, and (iv) soil analysis were calculated; only those between responses to ammonium sulphate and times of application were significant. Thus at Wenchi in 1951, Basa in 1954, and Tamale in 1956 the effects of the 60 lb. or early 80 lb. dressing of ammonium sulphate was increased by almost 90 lb. tubers per acre for every day the application was delayed after planting. This is in accord with results of soil nitrate measurements [6] which show that the nitrate level falls during the first rainy season and, after a small rise during the relatively dry month of August in the south, reaches its minimum in the second rainy season. It might be expected, therefore, that a really late application after the end of the first rainy season would meet plant demands when the soil nitrate was very low, and so be especially effective. The results of the 1954 and 1955 trials at Basa (Table 5) show, however, that such a late application was much less effective than the early one and that it gave no additional benefit to yams which had already received ammonium sulphate early. It is concluded that farmers should apply the ammonium sulphate to their yams during the first rains, and towards the middle rather than the beginning of that season.

In the areas along the main road from Ejura to Atebubu, and on through Basa to Kete Krachi, 1 cwt. ammonium sulphate per acre may be expected to increase yields by about 1,300 lb. and, assuming prices of 15*s.* and 42*s.* per cwt. respectively for the yam tubers and the fertilizer, to give a net profit of about £6. 12*s.* 0*d.* per acre. In Wenchi district the optimum rate of 80 lb. ammonium sulphate should provide a profit of £2. 0*s.* 0*d.* per acre. Around Tamale a mixture of 1 cwt. ammonium sulphate+1 cwt. single superphosphate should increase yields by 1,700 lb. and make a profit of about £10 per acre.

Rice in the Voltaian Savannah

All trials were of the standard 3^2 NP type and fertilizers were applied by

TABLE 4. *Effects of Ammonium Sulphate and Single Superphosphate on Yam Yields*

N_1 = Effect of 60 lb. ammonium sulphate per acre; P_1 = Effect of 60 lb. single superphosphate per acre.
N_2 = Effect of 120 lb. ammonium sulphate per acre; P_2 = Effect of 120 lb. single superphosphate per acre.

Locality	*No. of years*	*No. of trials*	*Mean yield in lb. tubers/ acre*	*Mean fertilizer effects in lb./acre*					*Interaction N_2P_2 as fraction of mean yield*	
				N_1	N_2	P_1	P_2	*L.S.D.* ($P = 0{\cdot}05$)	*No. of trials*	*Mean effects*
Ejura-Atebubu . .	3	61	6,840	448	1,337	168	351	450	52	−0·06
Wenchi District* . .	3	75	7,380	462	612	−454	6	390	57	0·06
Tamale	2	56	7,070	634	835	377	892	515	26	0·04
Yendi	1	23	6,010	330	886	144	538	480	..	..

* This includes Wenchi, Techiman, Nkoranza, and Kintampo.

TABLE 5. *Effects on Yam Yields of Different Times of Applying Ammonium Sulphate*

Locality	*No. of years*	*No. of trials*	*Mean tuber yields in lb./acre with ammonium sulphate treatments*				*L.S.D.* ($P = 0{\cdot}05$)
			No treatment	*80 lb. applied early*	*80 lb. applied late*	*80 lb. early + 80 lb. late*	
Basa	2	58	3,869	5,191	4,487	5,175	173

spreading them around the stands of rice after emergence. The rice was the local 'upland' variety, sometimes grown on ridges and sometimes interplanted with maize and guineacorn, but usually grown in pure stand on the flat, and never transplanted. The soils were mainly derived from sandstones: fairly well-drained brown medium sands on the upper slopes, and grey sands or clays in the valley bottoms. Some sites were flooded during the rains and many sites were affected by 'blast' (*Piricularia oryzae*). The local farmers' normal crop rotations have been described above under yam trials.

Table 6 shows mean yields and responses. Ammonium sulphate considerably increased yields, single superphosphate was less effective, and the negative NP interaction was so large that the effect of superphosphate was negligible on rice receiving ammonium sulphate. The results suggest that on these soils rice responds to sulphate as well as to nitrogen; in that case it would be unlikely that other nitrogen fertilizers would be more effective than ammonium sulphate. The mean effects of the double rate of ammonium sulphate were nearly twice those of the single rate, so that at these levels the response curve seem to be approximately linear. Taking the prices of ammonium sulphate and rice paddy in the area to be both about 42*s*. per cwt., the average profit from using 120 lb. ammonium sulphate would be £7. 8*s*. 0*d*. per acre.

Mean yields and responses were not significantly correlated with soil analyses for available phosphorus, organic carbon, nitrogen, or C/N ratio. But, in the twenty-two trials conducted between Ejura and Atebubu during 1951, later applications were significantly more effective with the 60 lb. rate of ammonium sulphate (N_1) and significantly less effective with the 120 lb. rate (N_2) than with earlier applications. A possible interpretation of this is that the most severe nitrogen (or sulphate) shortage occurred late in the season and could be remedied by the lower rate of ammonium sulphate only if it were applied about that time; whereas the higher rate with its longer residual effect was best applied sooner, when it could meet the early needs of the rice as well as satisfy the main late requirements.

The responses to ammonium sulphate after groundnuts were compared with those after cereals in the Ejura-Atebubu trials (Table 7). There is no indication that the preceding groundnut crops supplied nitrogen to the following rice.

The large effects of ammonium sulphate on the native farmers' rice contrast with the insignificant effects of fertilizers on swamp rice grown in the Department of Agriculture's rice fields sited in valleys subject to flooding during the rains. Twelve factorial trials covering all the chief rice stations in the country, and testing the effects of ammonium sulphate, cyanamide, single superphosphate, and muriate of potash, failed to indicate any significant yield responses of various varieties of swamp rice, although in many cases ammonium sulphate, and less frequently single superphosphate, increased vegetative growth. Both in these experiments and in the trials on native farms it was noticeable that superphosphate greatly encouraged growth of green algae early in the season, the P plots being readily identified from a distance by their colour.

TABLE 6. *Effects of Ammonium Sulphate and Single Superphosphate on Rice Paddy Yields*

N_1 = Effect of 60 lb. ammonium sulphate per acre; P_1 = Effect of 60 lb. single superphosphate per acre.
N_2 = Effect of 120 lb. ammonium sulphate per acre; P_2 = Effect of 120 lb. single superphosphate per acre.

Locality	*No. of years*	*No. of trials*	*Mean yield in lb. paddy acre*	*Mean fertilizer effects in lb./acre*					*L.S.D. ($P = 0{\cdot}05$)*	
				N_1	N_2	P_1	P_2	N_2P_2	*Main effects*	*Interaction N_2P_2*
Ejura-Atebubu . .	3	42	1,252	267	389	44	75	−103	87	106
Basa	2	69	1,198	269	645	56	159	−139	58	71
Mean for Ashanti . .	..	111	1,225	268	517	50	117	−121	52	64

TABLE 7. *Effect of Preceding Crop on the Response of Rice to Ammonium Sulphate*

Locality	*Year*	*Previous crop*	*No. of trials*	*Paddy yield without nitrogen lb./acre*	*Yield increase from 120 lb. ammonium sulphate*	
					expressed in lb./acre	*as per cent. of yield without* N
Ejura-Atebubu	1951	Groundnuts .	5	1,280	707	55
		Maize . .	14	965	507	55
	1952	Groundnuts .	6	731	445	61
		Maize . .	6	838	526	51

Maize in the Savannah Woodland and Fringing Forest

The trials were of standard 3^2 NP design in all cases, except in 1955 at Swedru and Nsawam when they were 2×3 NP factorials with the following treatments:

N = 0 and 60 lb. ammonium sulphate;
P = 0, 60 lb. single superphosphate (10·8 lb. P_2O_5), and 25 lb. triple superphosphate (10·0 lb. P_2O_5).

In each area except Sunyani about half the trials had cassava interplanted, and at Sunyani, Wenchi, and Nsawam about a quarter had plantain or cocoyam with the maize. Nearly all the remaining trials were of more or less pure stands of maize. Fertilizers were usually applied by ringing the stands after emergence.

Table 8 summarizes the yield results, including those for the mixed crops of maize and guineacorn around Tamale and Yendi which have already been reported by Nye [1].

In 1950 maize was devastated by rust (*Puccinia polysora*), and in 1951 and 1952 although the disease was progressively less virulent it reduced mean yields and probably the responses to fertilizers; ammonium sulphate treatments may have been especially affected, since this fertilizer, by increasing vegetative growth and perhaps delaying maturation, might be expected to enhance rust damage. However, ammonium sulphate significantly increased yields in all areas except Abor, the effect of 60 lb. usually being rather more than three-quarters that of 120 lb., indicating that the lower rate satisfied the greater part of the crop's demand. Responses to superphosphate were smaller, and again the response to the single dressing was usually more than half that for the double. The interaction NP was nowhere significant, but commonly negative in Ashanti and positive in the Nsawam and Swedru areas.

At present prices the only profitable responses were at Swedru, where, assuming prices per cwt. of 18*s*., 40*s*., and 25*s*. for grain, ammonium sulphate, and single superphosphate respectively, the optimum treatment would be about 35 lb. of each fertilizer; this should increase yields by nearly 210 lb. grain and provide a small net profit of 13*s*. per acre. If the equivalent amount of triple superphosphate (which in 1955 was significantly more effective than single super) is used, the estimated profit is about 16*s*. In addition the superphosphate should have a small residual effect on succeeding crops.

From over 160 correlation coefficients between yields, site histories, soil analysis, and times of application, the only significant values were those between yields or responses and plant population density, and between responses and time of application. At Swedru in 1952 and 1955, Nsawam in 1952, 1954, and 1955, and Wenchi in 1952, mean grain yields were increased by an average of just over 100 lb. for every extra 1,000 plants per acre. At Swedru in 1952 and 1955, Nsawam in 1952, and Wenchi in 1952, responses to 60 lb. ammonium sulphate were increased by nearly 40 lb. for every extra 1,000 plants per acre. Plant populations were measured at harvest time and were usually very low, the limits in the above trials being 1,500 and 20,000 plants per acre. If the

TABLE 8. *Effects of Ammonium Sulphate and Superphosphates on Maize Grain Yields*

N_1 = Effect of 60 lb. ammonium sulphate per acre; P_1 = Effect of 60 lb. single superphosphate per acre.
N_2 = Effect of 120 lb. ammonium sulphate per acre; P_2 = Effect of 120 lb. single superphosphate per acre.
P_T = Effect of 25 lb. triple superphosphate per acre.

Locality	*No. of years*	*No. of trials*	*Mean yield in lb./acre grain*	*Mean effects of 60 lb. rates in lb./acre*			*L.S.D. ($P = 0{\cdot}05$) N_1 and P_1*	*Effects of other rates as ratios to that of the 60 lb. rate*						*Remarks*
								N_2		P_2		P_T		
				N_1	P_1	N_1P_1		*No. of trials*	*Effects*	*No. of trials*	*Effects*	*No. of trials*	*Effects*	
Swedru .	4	78	699	154	130	24	55	51	1·4	51	1·2	27	1·5	
Nsawam .	3	74	872	102	−21	15	56	38	1·2	38	*	36	*	
Abor .	2	30	216	5	37	24	26	30	7·2	30	1·3	..	..	Low yields partly due to maize rust
Sunyani .	1	26	1,240	150	−33	−33	94	26	1·3	26	0	..	..	
Wenchi district.	2	45	558	106	28	−1	53	45	1·1	45	2·8	..	..	Includes Techiman, Nkoranza, Kintampo, and Wenchi areas
Tamale .	1	25	1,440	202	84	..	172	25	1·2	25	2·5	..	..	Maize+Guinea-corn
Yendi .	1	14	1,305	297	95	..	200	14	1·5	14	1·8	..	..	Maize+Guinea-corn

* At Nsawam in 1952 and 1954 P_2 averaged +106 lb./acre and P_1 = +30 lb./acre (mean of 38 trials); while in 1955 P_T = 210 lb./acre and P_1 = −123 lb./acre (mean of 36 trials).

farmer aimed at 15,000 to 20,000 plants per acre (e.g. a spacing of 2×3 ft. with two plants per stand), he should get higher yields and also greater responses to fertilizers; this might make the use of fertilizers around Swedru considerably more attractive. At Swedru in 1952 ammonium sulphate was applied between 6 and 13 days after planting and its effect on yield was significantly and positively correlated with the number of days interval; at Nsawam in 1954 the applications were 18 to 52 days after planting and the effects were significantly and negatively correlated with the number of days. About 3 weeks after planting would seem therefore to be about the optimal time to apply ammonium sulphate, earlier placements perhaps scorching the maize and later ones not meeting the young plants needs.

In general, fertilizers have been disappointing on maize; but in conjunction with close spacing (aiming at 15,000–20,000 plants per acre), careful applications (about 3 weeks after planting), and new high-yielding and more demanding varieties of maize, the use of low rates of ammonium sulphate and superphosphate may be economically attractive in the Swedru area.

Cassava in the Accra Plains near Katamansu

Nine trials were of the standard 3^2 NP type, whilst seven were of 2^2 NPK factorial design with rates as follows:

N = 0 and 120 lb. ammonium sulphate.
P = 0 and 120 lb. single superphosphate.
K = 0 and 60 lb. muriate of potash.

The soils were poorly drained with grey-brown sandy top soils overlying clayey or concretionary subsoils and an annual rainfall which is low (about 35 inches) and uncertain, so that the land is liable to suffer both drought and waterlogging. All trial sites had been under low grass and scrub bush for as long as could be remembered until they were tractor-ploughed and planted with cassava and calabash in 1955. Fertilizers were applied in May, about 1 to 3 months after planting, and the trials were harvested in August and September 1956.

Mean yields and main effects are given in Table 9; all interactions were small and non-significant. The effect of ammonium sulphate was odd, being outstanding in the 3^2 trials and poor in the 2^3 trials. However, it seems probable that a complete NPK mixture is required and 60 lb. ammonium sulphate + 120 lb. single superphosphate + 60 lb. muriate of potash has been recommended for further trials.

Note on Analysis of Top Soils (0–6 in.)

The pH was determined colorimetrically for samples from most of the trial areas; values varied from 5·9 around Basa up to 6·8 in the Nsawam area. Bray's acid-soluble + adsorbed phosphorus [5] was also determined in most cases and was usually found to be below 6 p.p.m. in the Accra Plains (Katamansu) and the far north (Bawku and Lawra), around 10 p.p.m. in the Ashanti savannah woodland (Wenchi, Ejura, Atebubu, and Basa) and over 20 p.p.m. in the southern savannah and fringing

TABLE 9. *Effects of Fertilizers on Cassava Yields*

N_1 = Effect of 60 lb. ammonium sulphate per acre.
N_2 = Effect of 120 lb. ammonium sulphate per acre.
P_1 = Effect of 60 lb. single superphosphate per acre.
P_2 = Effect of 120 lb. single superphosphate per acre.
K = Effect of 60 lb. muriate of potash per acre.

Locality	*No. of trials*	*Mean yield (lb./acre)*	*Effects of fertilizers treatments included in all trials*			*Effects of treatments not included in all trials*		
			N_2	P_2	*L.S.D.* ($P = 0{\cdot}05$)	K	N_1	P_1
Katamansu (Accra Plains)	16	10,600	1,895	2,488	890	1,510* (7 trials)	$0{\cdot}59 \times N_2$* (9 trials)	$0{\cdot}47 \times P_2$ (9 trials)

* = Although based on few trials, these responses were also significant.

forest (Abor, Swedru, and Nsawam). Organic carbon, nitrogen, and exchangeable cations were determined (mainly by methods described by Piper [7]) on samples from Nsawam, Swedru, Basa, and Katamansu. Average values are tabulated below:

Localities	C % *mean*	N % *mean*	C/N *ratio mean*	*Exchange capacity*	*Exchangeable cations*		
					Ca	K	Mg
				miligram equivalents per cent. (means)			
Nsawam and Swedru	1·32	0·165	8·0	11	7·3	0·52	1·6
Basa and Katamansu	0·65	0·05	13·5	5	2·5	0·35	0·9 (Basa only)

The figures for exchange capacity, exchangeable calcium, and exchangeable magnesium are only approximate; the calcium in the ammonium acetate leachate was measured directly by flame photometer (a rapid but not very accurate method) and magnesium was estimated by the Titan Yellow method.

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STUDIES ON FOWL SPERM

I. VIABILITY OF FOWL SPERMS AFTER STORAGE

II. SEASONAL VARIATION IN SPERM ABNORMALITIES

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Summary

The percentage of live sperms declined slightly after storage of undiluted semen for 72 hours at 4° C., when collected without milking the copulatory organ. The decline showed slight differences with the varying months and seasons; it was greater during summer than during winter.

The percentages of different forms of sperm abnormalities varied with the seasons. Head and tail abnormalities were most prevalent in the winter and summer respectively.

PART I

UNLIKE semen from most farm animals, avian semen has not been stored satisfactorily for any length of time. This is a result of high sperm concentration, and because the seminal fluid contains negligible amounts of nutrients [1]. Fowl sperms live and remain motile for periods ranging from several hours to 15 days under room conditions, and longer at lower temperatures (2° to 10° C.) [2, 3, 4, 5, 6, 7, 8]. Under freezing conditions (−4 to −79° C.) spermatozoa may retain their motility for as long as 14 months [6, 7, 9, 10]. Semen can be stored without serious loss in fertilizing capacity for only a few hours at room temperature [5, 11, 12], or lower (10° to 15° C.) [13, 14, 15, 16, 17]. A fertility of 25 per cent. has been obtained from quick-frozen semen (−6 to −79° C.) [6, 10].

Various diluents have been used to increase the keeping quality of stored semen. Glycerol has the property of protecting sperms against the harmful effects of very low temperatures. This protection is more evident in sperm motility than in fertilizing capacity. When semen was diluted to contain 15 per cent. glycerol and frozen to −79° C., full motility of sperms was restored after thawing [18]. However, the addition of glycerol to the semen in itself causes a serious reduction in the fertilizing power of the sperms. This may be due to its too rapid removal from the semen in the hen's oviduct [19]. However, semen treated with 15 per cent. glycerol and subsequently dialysed against Ringer's solution showed normal fertilizing power, and normal percentages of chicks were obtained from semen frozen in solid carbon dioxide (−79° C.) or in liquid air (−192° C.) [20]. By this treatment the fertilizing capacity may be kept for as long as 9 months [21].

Materials and Methods

Semen samples were collected from eighteen 1-year-old Fayomi cocks at 15-day intervals for one year. Collection was done without milking the copulatory organ [22]. Portions of the undiluted semen were kept in

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stoppered vials to study the effect of storage. They were cooled gradually in water in a double-walled glass beaker, to avoid low-temperature shocks, and kept in the refrigerator at 4° C. for 72 hours. Samples were examined before and after storage for live percentage, using semen films stained by the brom-phenol blue and nigrosin technique [23].

Results

The percentages of live sperms in both fresh and stored semen were progressively lower during spring and early summer (from March to June), after which they rose during autumn and winter to a maximum in February (Table 1).

TABLE 1. *The Effect of Storing Undiluted Semen on Percentage of Live Sperms*

Seasons	*Months*	*Live % in fresh semen*	*Live % in stored semen*	*% decline after storage*[1]
Winter	December	80·6	68·4	12·1
	January	83·8	72·3	11·5
	February	88·9	80·0	8·9
	Average	84·3	73·4	10·9
Spring	March	81·6	71·6	10·0
	April	59·9	48·9	11·0
	May	60·6	49·4	11·2
	Average	68·1	57·5	10·7
Summer	June	59·5	48·3	11·6
	July	65·1	53·5	11·6
	August	75·6	63·8	11·8
	Average	67·1	55·4	11·7
Autumn	September	78·1	63·7	14·4
	October	76·9	63·9	13·0
	November	86·1	77·9	8·1
	Average	80·4	68·6	11·8

[1] After storage for 72 hours at 4° C.

The prevailing climatic conditions in Egypt are long days with hot and dry weather in the summer, and short days with cold and wet weather in the winter. There could thus be a negative relationship between the live percentages and either air temperature or day length, or alternatively, a positive relationship between these percentages and relative humidity. The differences between months were highly significant ($P < 0.01$) in both fresh and stored semen. Seasonal differences were highly significant ($P < 0.01$) for fresh semen, but not significant for stored semen.

The average decline in live sperms in semen samples after storage was 11·8 per cent. The greatest decline occurred during September, and the lowest during November. The maximum decline occurred during autumn and the minimum in the winter. However, the variation in the percentage decline between months or seasons was not great.

During spring and summer the viability of sperms in fresh or stored semen was less than in winter or autumn. Low viability in fresh semen was followed by a marked decline in live sperms during storage.

Discussion

The poor storage properties of fowl semen are a hindrance to progress in artificial insemination in poultry. This poor storage may result from the techniques still used for semen collection from chickens and turkeys. Semen obtained by the massage technique without milking the copulatory organ [22] gives better storage results than that obtained by massage and milking. Contamination with the blood exudate from lymph folds and vascular bodies, resulting from the squeezing of the copulatory organs, adversely affects the survival time of sperms *in vitro* and the subsequent fertility [24]. In the present work, a high percentage of live sperms was successfully secured after storage for 72 hours at 4° C., which may be due to the fact that milking the copulatory organs was not practised. This is in agreement with the results of Lake [24] who obtained from stored semen as high a fertility as from fresh semen, when the semen samples were obtained without milking.

In the present work the storage of semen did not reduce the live-sperm percentage greatly. The decline in these percentages during storage showed slight differences with the seasons. The live percentage in fresh semen was lower, and its decline after storage was higher, in summer than in winter. It seems that the low percentage of live sperms in fresh semen has an effect on its storage capacity with a resulting low percentage of live sperms in the stored semen. Furthermore, in summer the semen is subjected at the time of collection to sudden shocks of intense light and high air temperature, which do not occur during winter. This might affect the resistance of the spermatozoa to storage conditions. For artificial insemination it may be better to restrict the insemination to the period from late autumn to early spring (from November to March), when the percentage of live sperms in both fresh and stored semen is highest, and its decline slowest. This period coincides with the normal breeding season, as commonly practised for several years past in Egypt. If artificial insemination is carried out over the whole year in climates such as that of Egypt, it is suggested that the use of a dark glass cup for collecting semen under a cover may be effective in preventing the bad effects of intense light, with improved storage capacity.

Part II

Sperm abnormalities have inhibitory effects on the induction of egg fertility by fowl spermatozoa [25, 26]. These abnormalities have also very deleterious effects on hatchability percentages [27]. Microscopic examination of spermatozoa is used to judge the fertilizing ability of fowl semen. Cocks are sterile when producing semen with high abnormal percentages (over 25 per cent.) [25]. Morphological studies of fowl sperms have shown that abnormalities include eleven [28] or twelve [29] forms of tail, head, and midpiece.

Materials and Methods

Semen samples were collected, prepared, and stained for microscopical examinations as described in Part I. The percentage of different forms of abnormal sperms and their totals were recorded.

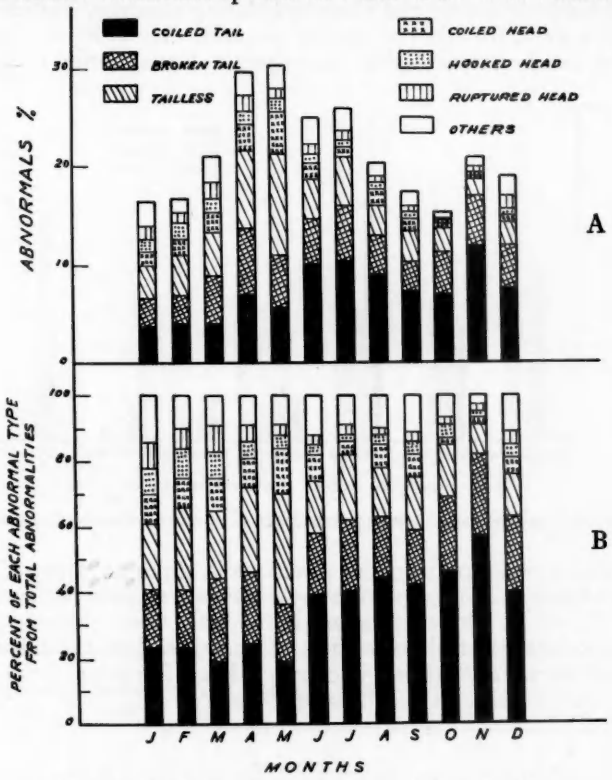

FIG. 1. Monthly variations in forms of abnormalities:
A = actual percentages.
B = per cent. of each abnormal type in total abnormalities.

Results

Coiled tail was the commonest type of abnormality, with a yearly average of 7·3 per cent. Broken tails and tailless sperms had a yearly average of 4·5 and 4·3 per cent. respectively. The yearly average percentages of head abnormalities, coiled, hooked, ruptured, and other types, were 1·7, 0·9, 0·9, and 1·9 respectively. The minimum percentages of coiled and broken tails were observed during January and February, whilst the minima for other forms occurred during November. Maximum percentages of coiled tails were found during November, and of the other forms from February to May. Generally, there was an increase in the malformations of heads and a decrease in deformations of

tails during the period from January to May. The highest percentages of deformities in tails were found during June to November, and the lowest for malformations in heads during October to December (Fig. 1).

With regard to seasonal variations, the percentages of tail deformities decreased during winter and increased during summer. Malformations in heads were at their lowest during autumn; they gradually increased until they reached their highest percentages during spring (Fig. 2).

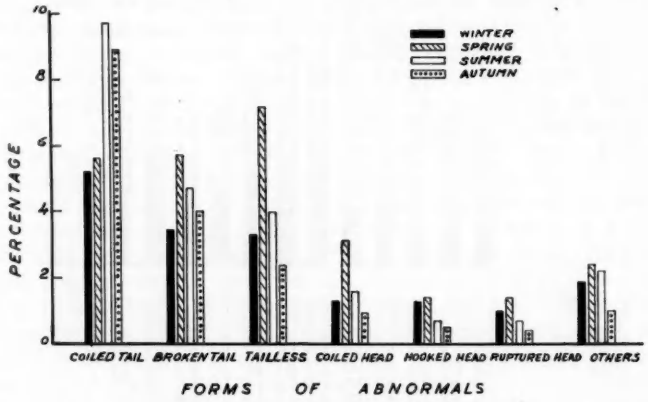

FIG. 2. Seasonal variations in percentages of abnormal forms of sperms.

There were wide and irregular variations in abnormal types of sperms between different cocks, without any obvious trend for the same individual (Table 2). However, some individuals were characterized by higher percentages of abnormalities of one type than the others (Fig. 3). The broken tail, tailless, and coiled head forms of abnormalities showed more variation than the other forms.

Discussion

The different forms of sperm abnormalities can be classified into two distinct types, one due to malformation in heads and the other due to deformities in tails. High abnormalities on heads occurred during winter months. This may be due to the depressed spermatogenic activity during winter, when the weather is generally cold and wet and the days are short. This may cause the production of incomplete types of sperms, resulting in the increase in head malformations. On the other hand, during summer, when the weather is hot and dry and the days are long, spermatogenic activity is at its highest [30] and the normal steps for the formation of complete sperms are undergone, with a consequent reduction in head malformations.

Tail deformities were particularly observed during the summer months and this may be due to the intense light and temperature shocks to which the spermatic fluid is subject at the time of collection.

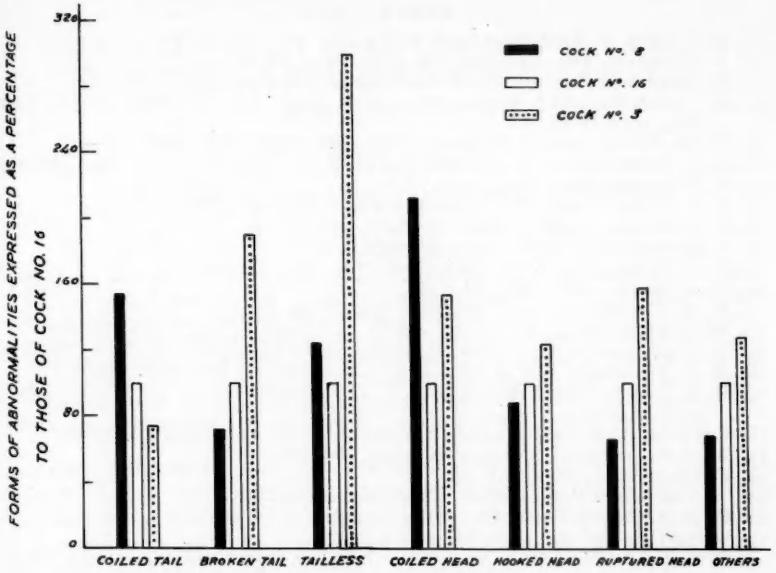

FIG. 3. Individual differences in percentages of forms of abnormalities.

TABLE 2. *Individual Differences in Percentages of Abnormal Forms of Sperms*

Individuals	*Coiled tail*	*Broken tail*	*Tailless*	*Coiled head*	*Hooked head*	*Ruptured head*	*Other forms*	*Total*
1 .	6·1	3·6	3·2	1·6	0·9	0·6	1·2	17·2
2 .	4·6	4·9	4·5	0·9	0·6	0·9	2·8	19·5
3 .	5·7	7·3	7·6	1·9	0·9	1·1	2·3	26·9
4 .	8·3	4·2	4·3	2·2	0·8	1·0	2·5	23·2
5 .	6·2	4·0	4·0	1·5	1·0	0·8	2·5	19·9
6 .	7·4	4·3	3·8	1·7	1·0	1·3	1·9	21·2
7 .	10·1	3·4	2·8	1·1	0·7	0·6	1·4	20·0
8 .	12·9	2·7	3·2	2·7	0·7	0·5	1·2	23·8
9 .	9·9	4·5	5·1	1·0	0·5	0·8	2·5	23·5
10 .	5·9	4·9	3·4	0·6	0·4	0·4	1·0	16·6
11 .	9·0	3·3	3·0	1·4	1·5	0·8	1·7	20·7
12 .	8·0	5·3	4·2	1·5	1·1	0·9	1·4	21·7
13 .	7·3	6·3	4·7	1·6	0·7	1·1	2·9	24·4
14 .	7·0	5·5	4·3	2·1	0·9	1·0	1·4	22·1
15 .	4·5	6·0	8·0	1·9	1·2	1·2	2·0	24·2
16 .	7·8	3·8	2·6	1·3	0·8	0·8	1·8	18·6
17 .	9·4	4·4	4·7	2·6	1·3	0·8	1·8	25·2
18 .	6·5	4·3	3·0	1·9	0·7	0·7	1·7	17·7
Av. .	7·3	4·5	4·3	1·7	0·9	0·9	1·9	21·4

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OBSERVATIONS ON VIRUS DISEASES OF CASSAVA IN RESISTANT AND SUSCEPTIBLE VARIETIES

I. MOSAIC DISEASE

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Summary

An account is given of the mosaic-disease resistance shown by varieties of cassava in field trials. Experiments showed that a high proportion of the plants of the moderately resistant varieties studied became infected in field trials in which they were exposed to infection by a very large vector population. When conditions favoured the resistance mechanism of the host, no symptoms of infection became evident, and the virus moved to the base of the plant, leaving the upper parts apparently free. Mosaic symptoms appeared more frequently if the growth of the host was interrupted at a time when there was a large vector population.

A MOSAIC disease of cassava is prevalent in all parts of East, West, and Central Africa and the adjacent islands. A description of early Amani studies on the several virus strains causing this disease and their mode of transmission has been given by Storey and Nichols [1], and reports of the work of breeding for resistance to them have been given by Nichols [2] and Jennings [3]. Immunity to the virus has not been found, but varieties are described as resistant if they do not readily show disease symptoms when exposed to infection. It was found that the degree of resistance shown varied at different places and at different times. A study of the host-virus relationship in resistant and susceptible varieties was therefore undertaken, and is reported in this paper.

The material studied was derived from backcrosses to cassava of interspecific hybrids between *Manihot esculenta* (cassava) and *M. glaziovii* (Ceara rubber), *M. dichotoma*, *M. catingae*, and *M. melanobasis*. Intervarietal cassava hybrids were also studied. The material was raised and maintained at Amani, which is situated in the Eastern Usambara Mountains, Tanganyika, at about 3,000 feet above sea-level. The plants were isolated from sources of infection, and cuttings from them were tested for virus resistance in field trials conducted at two centres: Mlingano, on the coastal plain of Tanganyika, 600 feet above sea-level; and Kizugu, in the foothills of the Usambara Mountains and also at 600 feet. A full description of these trials is given elsewhere [3].

Mosaic Resistance as Observed in Field Trials

Storey and Nichols [4], who studied the susceptible variety Mbarika at a site in this region, reported that the chances of mosaic symptoms appearing in plants of all ages from 2 to 8 months were low from August to October, began to increase in November, and were highest

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from March to May. This sequence corresponds with the increase and decrease of the insect vector population (*Bemisia* species); no evidence was obtained that the age of the plant influenced the chances of symptoms appearing. In conducting field resistance trials, it has therefore been the practice to plant in the short rains (October–November), so that the plants make their growth when virus transmission is high. Usually, in resistant varieties, only a small proportion of plants produce symptoms, but it is apparent from trials conducted over a long period that the chances of symptoms appearing in these varieties are greatest

TABLE 1. *The Appearance of Mosaic Symptoms in Plants of a Moderately Resistant and a Susceptible Variety following October Planting*

	37244E (Moderately resistant)		*Mbarika (Susceptible)*	
Month recorded	*No. of diseased plants*	*% of total diseased plants (56)*	*No. of diseased plants*	*% of total diseased plants (291)*
Oct.	0	0·0	8	2·7
Nov.	2	3·6	26	8·9
Dec.	4	7·2	90	30·9
Jan.	4	7·2	147	50·5
Feb.	5	9·0	185	63·6
Mar.	8	14·4	225	77·3
Apr.	29	51·9	268	92·1
May	47	84·0	286	98·3
June	52	92·9	291	100·0
July	56	100·0	291	100·0

in April and May; whereas in susceptible varieties a larger proportion of plants produce symptoms earlier than this. This is shown in Table 1, which gives the results for the intervarietal hybrid 37244E and the variety Mbarika, which were included as control varieties in twenty resistance trials carried out over a number of years. Two hundred and ninety-six plants of each variety were recorded.

Nearly all the Mbarika plants produced symptoms, and 77 per cent. of them did so before April. Only a small proportion of the 37244E plants produced symptoms, 70 per cent. of them in April and May.

In 1955 an attempt was made to record the intensity of mosaic symptoms. The intensity was scored on new growth and was on the following scale:

Score 1: A pale mild chlorosis with no leaf distortion.
Score 2: A normal yellow chlorosis with no leaf distortion.
Score 3: Chlorosis and slight leaf distortion but no reduction in leaf size.
Score 4: Leaf distortion accompanied by varying degrees of reduction in leaf size.

During March the new growth from diseased shoots of resistant plants showed a tendency to recover, but relatively intense symptoms were produced in April and May suggesting that the expression of resistance was weakened. This latter period coincides with the onset of

the long rains, the period of highest vector activity, and the time when plants reach their full size and begin to slow down in growth. The way in which these factors may interact to produce this result is not understood.

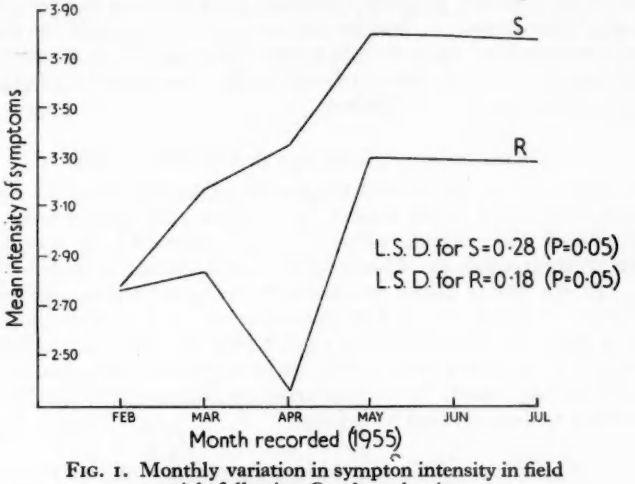

FIG. 1. Monthly variation in sympton intensity in field trials following October planting
R=Result from three trials containing predominantly resistant varieties
S=Result from one trial containing predominantly susceptible varieties

The results are given in Fig. 1. The mean intensity of symptoms is derived by dividing the total of the intensity scores by the number of plants which had shown symptoms up to the time of recording; that is to say, plants which recovered from an early appearance of symptoms are included but given a zero score in recordings subsequent to recovery.

TABLE 2. *Comparative Growth of* M. melanobasis *Hybrids and other Hybrids towards the End of the Growing Season*

Hybrid material	*No. of shoots marked on 1.6.56*	*Growth from 1.6.56 to 3.7.56*		*Growth from 3.7.56 to 3.8.56*	
		% shoots growing	*Mean growth*	*% shoots growing*	*Mean growth*
M. melanobasis hybrids	328	87	8·37 cm.	51	3·06 cm.
Other hybrids	210	84	1·96 cm.	31	0·52 cm.

Plants usually lose much leaf and become dormant at the end of the season, but, if they are maintained for more than one year, growth recommences in October or November. In resistant varieties, and with the exception of those derived from *M. melanobasis*, it is found that a

high proportion of plants in which symptoms have been recorded in the first season produce entirely symptom-free growth in their second. In contrast to this behaviour, derivatives of *M. melanobasis* frequently show the first symptoms of infection in the initial growth of the second season. These *M. melanobasis* hybrids continue growth for a longer period at the end of the season, a feature whose significance will be discussed later. A comparison between the growth of a group of *M. melanobasis* derivatives and that of other hybrids under the relatively cool conditions at Amani is given in Table 2.

The Expression of Resistance in Different Localities

The results from the coastal resistance trials described do not agree with those obtained in all areas. In Uganda and certain inland areas of Kenya and Tanganyika, varieties which showed only moderate resistance in their trials at Mlingano have maintained satisfactory resistance. On the other hand, instances have occurred on the coasts of Tanganyika and Kenya, and in Zanzibar, where high proportions of plants, of varieties which showed a good level of resistance at Mlingano or Kizugu, have succumbed in the early stages of trial. Table 3 gives an extract of the results from concurrent resistance trials at Mombasa, on the coast of Kenya, and at Kizugu.

TABLE 3. *Proportions of Cuttings which Established and of Plants which Produced Mosaic Symptoms in Trials at Mombasa and Kizugu*

Clone	% *of plants which produced symptoms*		% *establishment of cuttings*	
	Mombasa	*Kizugu*	*Mombasa*	*Kizugu*
46106/27 .	53	35	100	100
47213A/114 .	100	7	53	100
4026/20 .	100	60	83	100
Susceptible varieties .	100	100		

Growth conditions at Kizugu were ideal, but at Mombasa the trial was checked by a dry period soon after planting. It is apparent that 46106/27, which established and grew well at both sites, became diseased to a greater extent at Mombasa than at Kizugu; but that 47213A/114, which grew well at Kizugu, and very poorly at Mombasa, succumbed to a relatively greater degree at the latter site.

Experiment 1. The Effect of Cutting Back on Symptom Expression

The varieties mentioned in Table 3, together with the susceptible variety Mbarika, were further studied in the glasshouses at Amani. The material studied was from the isolated Amani stocks which were believed to be virus free. Plants of each of the four varieties were exposed for a period of 4 weeks to a large population of insect vectors in the presence of diseased infector material. They were then freed of all

insects, washed with a weak soap solution to remove all sedentary insect forms, and observed for a further 20 weeks in insect-free glasshouses. The plants produced mosaic symptoms in the following proportions: Mbarika, 37 out of 72 plants (52%); 4026/20, 18 out of 65 plants (18%); 47213A/114, 15 out of 45 plants (33%); and 46106/27, 9 out of 72 plants (13%). It was noted that symptoms did not readily appear when the plants were allowed to make uninterrupted growth after leaving the infection greenhouse: if, however, the growth of the plants was checked by cutting them back to two buds, symptoms often

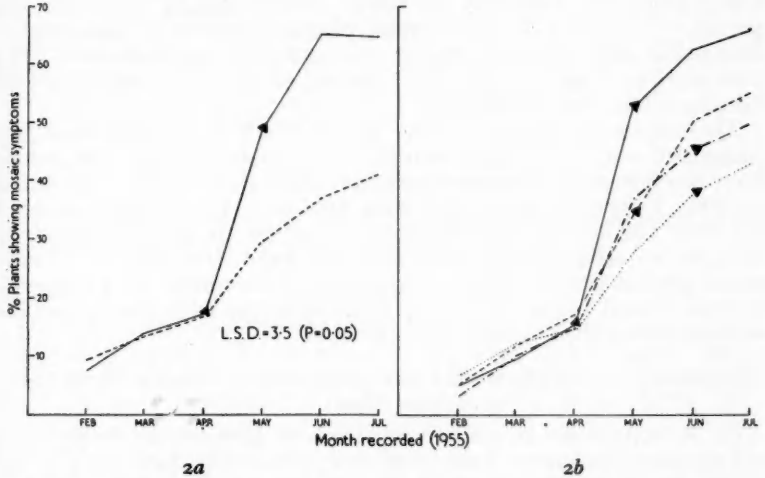

FIG. 2. The effect of plucking treatment on the appearance of symptoms in field trials

▲ When plucking treatment applied

FIG. 2*a*. Results for two trials, treatment replicated in each trial

FIG. 2*b*. Results for non-replicated treatments applied to the four replicates of a trial.

appeared in the initial growth of the new shoots that developed following this treatment. This was particularly true of the variety 46106/27 and less apparent in the susceptible varieties. The variety 47213A/114 established badly and made poor growth throughout this experiment. Its resistance, as measured by the proportion of plants which produced symptoms, was lower than that of 46106/27: its relative resistance followed that recorded at Mombasa, where its vigour was also poor, rather than that at Kizugu, where it grew well.

Experiment 2. The Effect of Checks in Growth on Symptom Expression in Field Trials

The result obtained in the glasshouse suggested that the incidence of mosaic in the routine resistance trials at Mlingano might be increased

if the plants were subjected to checks in growth; this would enable a more rigorous selection for mosaic resistance to be carried out. Treatments were therefore superimposed on the trials and consisted of plucking out the terminal buds of the plants: this caused extension growth to cease for 10 to 14 days before it was resumed from lateral buds just below the apex. Since there exists a natural tendency for moderately resistant plants to produce mosaic symptoms during April and May (Table 1), it was considered that plucking might be most effective if applied at this time. This was tested in two trials, in each of which two of the four replications were plucked in early April and again in early May, and the other two left untreated. (Each replicate contained from 300 to 330 plants.) In other trials, plucking treatments were superimposed at different times of the year and were not replicated. The trials were recorded monthly until the end of the season, when most of the plants had shed their leaves.

The results are shown in Fig. 2: the effect of the treatment was immediate and considerable; symptoms appeared in the initial growth from the dormant buds and must have been due to infections which occurred before the treatments were applied. When treated in April and May the incidence of mosaic recorded for the varieties 46106/27 and 4763/16 was greater than that recorded in the Mombasa trial. Treatments applied late in the season appeared to have little effect (Fig. 2*b*). In both treated and untreated replicates of all the trials the susceptible varieties succumbed completely to mosaic.

Experiment 3. *The Occurrence and Distribution of Virus in Symptom-free Plants*

In this experiment an attempt was made to demonstrate the presence and distribution of virus in symptom-free plants which had been exposed to infection in field resistance trials. The material studied was taken from resistance trials conducted in 1953–4 and in 1954–5. The material taken from the 1953–4 trials consisted of (1) the two control varieties, 37244E and 46106/27, from the Mlingano trials, and (2) miscellaneous material from Kizugu. The trials at Mlingano were planted in October 1953, and the plants chosen for experiment had been recorded as symptom-free in each monthly recording made from January to the end of July. They had made good growth throughout the trials and cuttings were taken for experiment in August 1954. The material taken from Kizugu was mostly of the varieties 37244E and 4032, but included a few plants of other hybrids. The establishment of all the varieties at this site had been bad, and subsequent growth poor. The plants had also been recorded monthly, but, although they were of the same age as the Mlingano series, they were small and immature when cuttings were taken in August. The material taken from the 1954–5 trials consisted of (1) two resistant varieties, 4763/16 and 46106/27, from Mlingano trials; (2) the same varieties from a trial at Kizugu where growth was particularly vigorous; and (3) the same varieties from a trial at Pongwe, near Mlingano. These trials had all been planted during the short rains of 1954, and recorded at monthly intervals as before. Cuttings

were taken from Mlingano and Kizugu in August 1955. At Pongwe, the cuttings were taken in November, when the variety 4763/16 was just beginning to form new shoots for its second season's growth. The variety 46106/27 had not done so.

TABLE 4. *Percentages of Plants which showed Mosaic Symptoms in Field Resistance Trials*

	Mlingano	*Kizugu*	*Pongwe*
1953–4 season			
37244E (True cassava hybrid) . . .	21	36	..
46106/27 (Ceara hybrid)	17	..	..
4032 (Ceara hybrid)	..	40	..
Susceptible varieties	100	100	..
1954–5 season			
46106/27	50	..	7
4763/16 (Ceara hybrid)	31	..	..
46106/27+4763/16	40	..	1
Susceptible varieties	100	100	100

The percentages of plants which produced mosaic symptoms in the trials at the several sites is given in Table 4.

Method

From each plant cuttings were taken from various levels, labelled, and planted at Kizugu. The sample taken included all the basal cuttings (B1), two levels of cuttings immediately above them (B2 and B3), all the 'uppermost' cuttings (U), and 'mid-upper' cuttings (MU). The 'mid-upper' cutting was one from the basal end of the branch from which the uppermost cutting was taken; the 'uppermost' cutting was the most terminal cutting that could be taken from mature wood. Since the plants branched at different levels it was inevitable that the number of cuttings tested for successive levels above the base increased progressively. Some of the very poor Kizugu plants of the 1953–4 season were only able to supply four levels of cuttings; hence the mid-upper cutting was not always represented in this series.

As soon as the cuttings began to grow they were recorded for mosaic symptoms. In addition, it was possible to observe the new growth from the stumps (1–3 in. high) of the plants chosen at Kizugu. All the cuttings making symptom-free growth were then twice cut back to help bring out symptoms of latent virus. This did not eliminate the possibility that virus might remain in cuttings which were still symptom-free at the end, but experience elsewhere has shown that symptoms can rarely be induced in plants which fail to show them after such treatment. Since vector activity is extremely low at this time of year (vectors were not seen until late November), it is considered that the symptoms which appeared were almost certainly due to the presence of virus in the original cuttings, and not to new infections. The symptoms were usually seen in the first leaves of the shoot that developed after planting the cutting, or after cutting it back.

Results

In the Kizugu series from the 1953–4 trials, mosaic was in some cases recorded in the new growth produced by stumps of plants whose cuttings all made entirely symptom-free growth.

TABLE 5. *Detection of Virus in Cuttings from Symptom-free Plants taken from Mlingano (Ml.), Kizugu (Kiz.), and Pongwe (Pwe.)*

Material	No. of plants studied				Plants in which virus was detected							
	Ml.	Kiz.	Pwe.	Total	Ml. No.	Ml. %	Kiz. No.	Kiz. %	Pwe. No.	Pwe. %	Total No.	Total %
1953–4 trials												
37244E	20	28	..	48	2	10	6	21	..	..	8	17
46106/27	21	..	..	21	6	28	..	..	..	..	6	28
4032	..	39	..	39	..	..	15	38	..	..	15	38
Others	..	25	..	25	..	..	9	36	..	..	9	36
Total	41	92	..	133	8	20	30	33	..	..	38	29
1954–5 trials												
46106/27	24	18	26	68	9	38	2	11	5	19	16	24
4763/16	33	18	30	81	13	39	5	28	8	27	26	32
Total	57	36	56	149	22	39		19	13	23	42	28

TABLE 6. *Distribution of Virus in Cuttings from Symptom-free Plants*

Level of cutting	38 plants from 1953–4 series			42 plants from 1954–5 series		
	Cuttings tested	Virus detected		Cuttings tested	Virus detected	
		No.	%		No.	%
B1	51	28	55	81	31	38
B2 . .	55	15	27	97	21	22
B3 . .	57	10	18	147	16	11
MU .	50	12	24	284	25	9
U . .	74	12	16	314	27	9

The distribution of virus in the cuttings from the symptom-free plants in which it was detected is given in Table 6. In the 1954–5 series, and to a lesser degree in the 1953–4 series, a tendency for the virus to be limited to the basal cuttings was noted. In 21 of the 38 symptom-free plants in which virus was detected in 1954, and in 19 of the 42 in which it was detected in 1955, the virus was diagnosed only in the growth from basal cuttings: all the uppermost ones produced entirely symptom-free growth.

In addition to the symptom-free plants tested from the 1953–4 trials, six plants were tested which had shown symptoms during the early stages of the resistance trial but had later recovered. In four of these, only cuttings from the base of the plant produced diseased growth, the virus in another was found to be more irregularly distributed, and no virus was traced in cuttings from the sixth.

Experiment 4. The Distribution of Virus in Plants during their Second Growing Season

The object of this experiment was to investigate the distribution of virus in a miscellaneous group of plants of resistant varieties which were in their second growing season. The plants tested included some which had shown symptoms in their first season's growth and had produced entirely symptom-free growth in their second, some which were showing symptoms when cuttings were taken, and others which had not shown symptoms throughout the experiment. The plants were from a trial at Kizugu which was planted in October 1953. They had made exceptionally good growth in the early part of 1954, lost most of their first season's leaf during the period from July to October, and had put on a new leaf canopy by the time the cuttings were taken in February 1955. The procedure used was the same as for Experiment 3, but the cuttings were planted at Amani instead of at Kizugu.

Twenty-two plants were tested in which definite symptoms had been recorded in one or more of the monthly recordings made during the first season, but not in the second season. No symptoms of mosaic virus could be obtained in cuttings from ten of these, mosaic symptoms appeared in a few basal cuttings from eight, and in cuttings from various parts of the remaining four.

The most notable result from plants which were showing mosaic symptoms when the cuttings were taken was that in fifteen of the twenty-nine plants studied, symptoms appeared only in cuttings from one branch out of the three or four tested, while in five other plants, only cuttings from one or two of the branches plus a basal cutting of another produced symptoms. This was in spite of the fact that many of the plants had shown symptoms 15 months before.

Twenty-five plants of the control varieties which had not shown symptoms throughout the experiment were also tested: virus was diagnosed in a few basal cuttings from one plant, and in terminal cuttings of two others.

Discussion and Conclusions

Storey and Nichols [1], studying the susceptible variety Mbarika, found that no successful infections of mosaic virus occurred when insect vectors fed on mature leaves, but, if a large number of vectors were allowed to feed on an immature leaf at the shoot apex, symptoms usually appeared within 2 to 3 weeks. Their results suggested that the virus moved rapidly downwards in the plant but only slowly laterally or upwards. In the studies reported here, it seems that plants of resistant varieties frequently become infected with mosaic virus without showing disease symptoms, or they may show only transient symptoms. Further, if failure to induce symptoms can be taken as evidence for absence of virus, it appears that the virus does not always remain systemic in the stems: it frequently appears to be confined to basal parts of the plant, at least at the end of the growing season.

The glasshouse experiment, and later the plucking trials carried out in the field, showed that many more plants could be induced to show

symptoms of infection if their growth was checked by pruning or plucking; but the effectiveness of the plucking treatment applied to the field experiment appeared to diminish after April (Fig. 2). During March and April the vector population is large and many virus inoculations must take place; the population decreases rapidly in subsequent months. The decreased effectiveness of the plucking treatments could therefore be explained by postulating that virus moves away from the apices soon after they have been inoculated: an hypothesis which is supported by the apparent distribution of virus frequently found at the end of the season.

Resistance to mosaic therefore seems to be due, in part at least, to an ability of the plant to restrict the virus to its basal parts where it can do no harm. Although virus was traced in less than a third of the symptom-free plants which had been exposed to infection, this does not necessarily mean that the remaining plants were virus free, since the method used to induce symptom expression is known to have limitations, especially if the possibility of the virus becoming completely localized in the roots is considered. The nature of resistance in more recently bred varieties is probably more complex: these varieties did not show symptoms when subjected to trials in which plucking treatments were used, and also remained symptom-free in a coastal trial in which varieties such as 46106/27 and 37244E succumbed almost completely [3]. Later work showed that they were not immune.

It is frequently reported for biennial or perennial species that an association exists between the direction of virus movements in the plant and that of food materials in the phloem. In cassava, movements of food materials in the stem must be predominately downwards during the growing season, but, since storage tissues are also abundant in the cortex of the stem, it is difficult to assess the extent of upward movement which might take place when the new season's growth commences after the dormant period. Attempts were made to detect an upward movement of virus in the plant at this time, but when cuttings were taken from symptom-free plants at Pongwe in November (Experiment 3), and at Kizugu in February of the second growing season (Experiment 4), the tendency for diseased cuttings to be confined to those taken from basal levels of the plant was as great as when plants were studied early in the dormant period. It is also during the initial growth of the second season that many hitherto diseased plants of resistant varieties are found to become symptom-free.

No relation was found between the percentages of symptom-bearing plants which occurred in the field trials and the percentages of symptom-free plants which were later found to contain virus. For example, the percentage of symptom-bearing plants in the 1953–4 trials (Table 4) was approximately the same for the true cassava hybrid 37244E as for the Ceara hybrids 46106/27 and 4032 at Mlingano and Kizugu respectively, but at both sites virus was traced in cuttings from a much greater percentage of the symptom-free plants of the Ceara hybrids than of 37244E. It was also traced in cuttings from a greater percentage of the symptom-free plants from Kizugu than from those at Mlingano (Table 5). In the

1954–5 trials the percentage of symptom-bearing plants was greater for 46106/27 than for 4763/16, but a greater percentage of the symptom-free plants of the latter were found to contain virus. It is also apparent in the 1954–5 trials that, whereas the proportion of symptom-bearing plants at Mlingano was similar to that of the symptom-free plants in which virus was detected, this was not so at Kizugu and Pongwe, where there was less than 1 per cent. of symptom-bearing plants and virus was detected in 23 and 19 per cent. of the symptom-free plants at the respective sites. These results suggest that there is a greater chance of detecting virus in stems of symptom-free plants which lose their leaf and become dormant late in the season than in those which do this relatively early. In this respect the variety 37244E is early, 46106/27 and 4032 are intermediate, and 4763/16 is late. Moreover, in the 1953–4 trials the Kizugu plants were much less mature than the Mlingano ones. The difference between the sites in the 1954–5 series, however, cannot be explained in this way; in this case it is probable that another factor, possibly an edaphic factor, limited the occurrence of symptom-bearing plants at Kizugu and Pongwe.

The observation that the period during which a plant makes growth may be important helps to explain the anomalous behaviour of hybrids derived from *M. melanobasis*. These make growth over an exceptionally long period (Table 2), and consequently have an exceptionally short dormant period. Possibly, in such cases, the virus content of the stems remains so high that there is little chance of recovery taking place in the new season's growth.

The result obtained when plucking treatments were applied to the field trials emphasizes the magnitude of the influence which environmental factors may have on the host-virus interaction. Hence, it is tempting to speculate that the difficult growing conditions encountered in the Mombasa trial could account, at least in part, for the failure of the resistant varieties there. Further, since the variety 47213A/114 has proved to be very sensitive to difficult growing conditions, the conflicting results recorded for its mosaic resistance in different trials suggest that there are two aspects of resistance: firstly, resistance which directly inhibits the activity of the virus, and secondly, resistance to conditions which are unfavourable to the growth of the plant. The latter aspect includes ability to establish and grow away quickly under difficult conditions, and is related to the degree to which a variety is adapted to a given set of conditions. This would explain why the relative resistance of varieties among themselves sometimes varies with the conditions under which they are tested. However, it should be emphasized that the part played by differences in virus strains in East Africa is not understood. Similarly, there are indications that edaphic factors may have a very important influence on the expression of resistance. For example, in the 1954–5 and 1955–6 resistance trials at Mlingano, the writer found considerable variation in the incidence of mosaic in the resistant control varieties, the disease being most prevalent in the highest-yielding trials, and in the highest-yielding replicates of individual trials. In the same way differences in the vector population, which varies considerably with

altitude, may also be important. A knowledge of all these factors will be necessary before the considerable differences in the behaviour of resistant varieties reported from different parts of East Africa can be understood.

Acknowledgements

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MANURING OF COTTON IN WEST PAKISTAN[1]
II. EFFECT OF DATE OF SOWING, IRRIGATION, SPACING BETWEEN ROWS, AND RATE OF MANURING ON THE YIELD OF SEED COTTON

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Summary

The effect of dates of sowing, irrigation, manuring, and spacing between rows on the yield of seed cotton was studied at five different stations representing different varietal zones. The best sowing dates for the Lyallpur, Wazirkot, Montgomery, Khanewal, and Multan tracts were the second half of May, the first half of May, late May to early June, the first half of June, and the first week of June respectively. Four irrigations were enough, provided the total rainfall from May to December was not less than about 8 inches. When the rainfall was less than this, better results were obtained by using six irrigations.

The use of ammonium sulphate on cotton, at rates of 50 or 75 lb. of N per acre, were economic (at prevailing prices) only if the crop was sown at the earlier date appropriate for the district. In these circumstances there was a greater margin of profit with the application of 75 lb. N per acre. The other most suitable conditions for the use of ammonium sulphate were 2-foot spacing between rows and six irrigations. This spacing gave the best results at all stations except Wazirkot. The best results were obtained by the use of 75 lb. N per acre, 2-foot spacing, four to six irrigations (depending upon the rainfall), and early sowing. Date of sowing was of the greatest importance. If cotton was sown late, then the effects of nitrogen, irrigation, and the correct spacing were masked. The late-sown cotton also suffered most from attacks of whitefly and jassid.

DATES of sowing have a specially profound effect on the yield of cotton in West Pakistan because temperatures are liable to undergo unpredictable changes during the sowing period. The number of plants per acre, and the total quantity of water applied, also greatly influence yields. During summer there is great competition for water, which becomes a limiting factor. The soils of West Pakistan are specially deficient in nitrogen, which is also an important limiting factor. The study of the effect of these factors and their interactions on the yield of seed cotton is thus of great importance. Afzal [1] has studied the effect of dates of sowing, manuring, irrigation, spacing, and variety on the yield of cotton. The findings of the Department of Agriculture of the former Punjab regarding the effects of such factors have been summarized by Milne *et al.* [2] and Roberts and Singh. The present paper deals with a critical experimental re-examination of this subject.

Material and Methods

Experiments over 4 years (1953/4 to 1956/7) were conducted at five stations, using cotton varieties L.S.S., 238F, and 124F, as described in

[1] Publication of the Department of Agriculture, West Pakistan. This scheme was partially financed by the Pakistan Central Cotton Committee, Karachi.

Part I of this series [4]. The experiments were laid out in a split-plot design, the main plots being successively split for dates of sowing, irrigations, fertilizers, and spacings.

Dates of sowing (D_1, D_2, and D_3) at Lyallpur, Wazirkot, and Montgomery were: 15 May, 30 May, and 15 June; 15 April, 1 May, and 15 May; and 25 May, 10 June, and 23 June, respectively; and 1 June, 15 June, and 30 June at Khanewal and Multan.

There were two levels of irrigation, I_1 and I_2, i.e. four and six irrigations of 3 inches each (in addition to the one applied for the preparation of the land). Only two levels of irrigation were studied because a third and higher rate was not realistic under prevailing conditions.

Nitrogen fertilizer was applied as ammonium sulphate broadcast between the rows in one dose at the pre-flowering stage and followed by irrigation. The three rates, M_1, M_2, M_3, were respectively 0, 50, and 75 lb. N per acre.

The three spacings between the rows, S_1, S_2, and S_3, respectively, were 2, 2½, and 3 feet.

There were three replications in randomized blocks. The smallest sub-plot size was $\frac{1}{40}$ acre. Cotton followed wheat in all experiments.

Results and Discussion

Mean yields of seed cotton in each of the 4 years, and for each combination of the four treatment factors, at each of the stations, were examined statistically by the analysis of variance to study the effects of the various factors. In the results and discussion which follow, effects for which the value of P is less than 0·05 or 0·01 are designated as 'significant' or 'highly significant' respectively.[1]

Four-year mean yields for each combination of treatment factors are given for each station, and as general means for all five stations, in Table 1. The effects of each treatment factor are first considered separately, station by station, and then as general means of all stations together over the 4-year period, with the effects of the other three treatment factors averaged out in each case.

The interrelations between the effects of each treatment factor and variations in the other three treatment factors are then examined.

The Effects of Each Treatment factor considered separately

Date of sowing. Date of sowing affects yields very markedly. Sometimes water is available late or there is water scarcity at the time of sowing; the cultivators may be busy with the threshing of wheat; or sowing may be delayed purposely to avoid the incidence of root-rot. Dates of sowing varied with the variety and the zones specified for these varieties.

Lyallpur. Cotton sown from mid-May up to the end of May yielded higher throughout than that sown in mid-June, though the differences were not significant during the first 3 years, but were highly significant

[1] Space does not permit publication here of the detailed yield data at each station separately for each year, but these can be obtained by application to the authors.
EDITOR.

TABLE 1. *Four-year Mean Yields of Seed Cotton for each combination of Treatments, for each Station and General Means for all Stations together. Maunds* per acre*

Serial no.	*Treatment combination†*	*Lyallpur*	*Wazirkot*	*Mont-gomery*	*Khanewal*	*Multan*	*General mean for all stations*
1	$D_1I_1S_1M_1$	18·87	10·90	14·11	10·59	16·13	14·10
2	$D_1I_1S_1M_2$	21·18	11·89	14·64	10·59	19·60	15·58
3	$D_1I_1S_1M_3$	23·62	10·35	16·13	11·78	19·87	16·35
4	$D_1I_1S_2M_1$	18·69	9·47	13·47	9·18	16·46	13·43
5	$D_1I_1S_2M_2$	20·80	11·17	13·49	13·42	18·46	15·47
6	$D_1I_1S_2M_3$	21·15	10·27	15·98	11·61	18·66	15·53
7	$D_1I_2S_2M_1$	17·44	9·61	13·71	9·41	16·29	13·29
8	$D_1I_2S_2M_2$	20·94	11·31	13·56	9·42	17·37	14·52
9	$D_1I_2S_2M_3$	20·16	10·60	14·25	10·25	16·54	16·36
10	$D_1I_2S_1M_1$	19·45	13·18	16·45	13·93	18·94	16·39
11	$D_1I_2S_1M_2$	22·45	15·38	19·06	14·72	20·46	18·41
12	$D_1I_2S_1M_3$	21·45	16·49	18·97	15·04	19·81	18·35
13	$D_1I_2S_2M_1$	18·62	14·44	15·47	14·50	18·33	16·27
14	$D_1I_2S_2M_2$	22·11	13·97	18·09	15·11	18·44	17·54
15	$D_1I_2S_2M_3$	22·72	15·78	18·16	14·39	18·99	18·01
16	$D_1I_2S_2M_1$	18·84	16·65	14·72	13·53	15·77	15·90
17	$D_1I_2S_2M_2$	17·92	14·28	16·86	12·19	20·50	16·35
18	$D_1I_2S_2M_3$	22·00	15·99	18·14	14·22	18·35	17·76
19	$D_2I_1S_1M_1$	17·86	10·52	14·65	10·26	14·89	13·64
20	$D_2I_1S_1M_2$	20·82	15·09	14·49	11·92	15·56	15·58
21	$D_2I_1S_1M_3$	20·65	12·56	14·44	11·95	15·80	15·08
22	$D_2I_1S_2M_1$	17·76	10·68	13·15	11·08	13·38	13·21
23	$D_2I_1S_2M_2$	19·21	11·66	13·79	10·95	15·43	14·19
24	$D_2I_1S_2M_3$	19·13	12·65	13·80	11·62	14·92	14·42
25	$D_2I_1S_2M_1$	15·77	9·76	12·79	10·22	16·21	12·95
26	$D_2I_1S_2M_2$	17·18	12·76	12·12	9·28	14·19	13·11
27	$D_2I_1S_2M_3$	18·24	13·59	13·22	9·73	13·47	13·65
28	$D_2I_2S_1M_1$	19·7	12·92	17·27	13·98	16·17	15·99
29	$D_2I_2S_1M_2$	20·19	14·32	17·53	14·23	17·33	16·72
30	$D_2I_2S_1M_3$	21·76	17·87	18·18	14·28	17·44	17·91
31	$D_2I_2S_2M_1$	17·62	13·39	16·59	13·74	15·78	15·42
32	$D_2I_2S_2M_2$	20·28	15·57	16·68	14·24	15·97	16·55
33	$D_2I_2S_2M_3$	19·86	15·29	18·66	13·35	15·52	16·53
34	$D_2I_2S_2M_1$	17·06	12·87	15·01	12·95	14·81	14·54
35	$D_2I_2S_2M_2$	17·24	12·77	16·41	12·46	15·37	14·85
36	$D_2I_2S_2M_3$	20·65	14·64	15·48	13·92	14·95	15·93
37	$D_3I_1S_1M_1$	12·08	11·28	13·62	8·57	12·56	11·62
38	$D_3I_1S_1M_2$	11·56	13·01	13·41	9·89	13·49	12·27
39	$D_3I_1S_1M_3$	12·22	14·51	14·29	9·16	17·64	13·56
40	$D_3I_1S_2M_1$	10·87	12·43	11·94	7·88	13·38	11·30
41	$D_3I_1S_2M_2$	10·88	12·25	12·51	8·93	13·38	11·79
42	$D_3I_1S_2M_3$	11·98	12·83	12·82	8·19	13·96	11·96
43	$D_3I_2S_2M_1$	9·87	10·34	10·93	8·10	12·45	10·34
44	$D_3I_2S_2M_2$	10·46	12·93	12·41	7·68	12·57	11·21
45	$D_3I_2S_2M_3$	10·26	13·41	11·31	7·73	13·98	11·34
46	$D_3I_2S_1M_1$	13·83	12·95	14·23	7·68	19·15	13·56
47	$D_3I_2S_1M_2$	13·43	11·84	14·11	9·72	14·95	12·81
48	$D_3I_2S_1M_3$	13·66	14·34	14·38	8·47	11·31	12·43
49	$D_3I_2S_2M_1$	12·51	13·03	13·87	8·19	12·81	12·02
50	$D_3I_2S_2M_2$	13·23	12·79	15·6	7·94	13·83	12·59
51	$D_3I_2S_2M_3$	13·69	14·99	11·83	10·45	13·40	12·87
52	$D_3I_2S_2M_1$	9·69	10·84	12·91	7·91	11·52	10·57
53	$D_3I_2S_2M_2$	10·14	12·75	12·19	7·42	12·93	11·09
54	$D_3I_2S_2M_3$	13·67	14·22	12·83	7·73	13·89	12·47

* 1 maund = 82 lb. † For key to treatment combinations see p. 36.

in the fourth year for mid-May against mid-June sowing. However, mid-May sowing was not significantly different from sowing by the end of May. Thus the optimum time of sowing in this tract was from mid-May to end of May.

Wazirkot. Sowing in early or mid-May resulted in higher yields than mid-April sowing for 3 years, the differences being significant in 1955–6 only. In the fourth year the effect of date of sowing was nullified by heavy insect attack, which was worst in late-sown cotton. The best sowing time for cotton in this zone was, therefore, from early to mid-May.

Montgomery. The effects of sowing dates were significant during two years out of three: significant in 1953–4 and highly significant in 1956–7. Whereas cotton sown in the last week of May significantly outyielded that sown at the beginning of the second week of June in 1 year, and at the beginning of the third week of June in 2 years, that sown at the beginning of the second week of June was significantly outyielded by that sown in the third week of June in 1 year and was equal to May sowing in another year. Sowing of cotton from 25 May to 10 June in this tract thus gave the best results.

Khanewal. The effects of sowing dates were not significantly different for 2 years, but they were highly significant in the other 2 years (1955–6 and 1956–7). Mid-June sowing was slightly better than that made in the first week of June. Cotton sown in late June was definitely inferior in yield. Cotton sown during the first 2 weeks of June thus gave the best yields.

Multan. The situation with respect to statistical significance was similar to that at Khanewal. Cotton sown in the first week of June gave highest yields throughout, whilst the yields from sowings in mid-June and late June were similar. Thus the early June sowings were the best.

General. The effects of date of sowing at individual stations were largely non-significant, because they were vitiated by other factors, such as incidence of 'tirak' or premature opening of bolls, insect and pest attacks, and at times by drought. However, these are all factors which are correlated with weather conditions and hence with dates of sowing, thus contributing to variation in yields from year to year and place to place. However, the overall effect was very marked, early sowing being better than medium and both being greatly superior to late sowing, the mean yields in maunds per acre being: early, 16·1; medium, 15·0; late, 12·0. Late sowing was thus inferior to early sowing by 29 per cent. (see Table 3, p. 41).

Irrigation. In studying the effect of irrigation, the amount of rainfall and its distribution during the period May to December are very important. Rainfall records were kept at all the stations and are given in Table 2.

The effect of differences in irrigation at any station at which the total rainfall from May to December was about 8 inches was non-significant. At Montgomery in 1954–5 and Khanewal in 1956–7 floods completely disrupted the irrigation system, so that water was not available when needed. During the years when these experiments were conducted

there was, on the whole, a marked increase in the rainfall in West Pakistan.

Lyallpur. As the total rainfall from May to December during all the years was about 8 inches or more, the effect of differences in the irrigation was non-significant in all the years, though higher yields were obtained with six irrigations over those with four.

Wazirkot. The differences in the effect of irrigation were highly significant only in 1954–5, when the total rainfall from May to December was only 3·05 inches; during the two subsequent years the total rainfall exceeded 8 inches, and the differences in the effect of irrigation were non-significant.

TABLE 2. *Rainfall in inches, May to December*

	Station				
Year	*Lyallpur*	*Wazirkot*	*Montgomery*	*Khanewal*	*Multan*
1953 .	11·55	..	10·84	8·33	..
1954 .	7·77	3·05	10·23	4·71	..
1955 .	13·68	16·35	9·59	6·30	8·65
1956 .	13·35	19·00	10·16	3·16	11·89
Mean.	11·58	12·86	10·20	5·62	10·27

Montgomery. Here again, as at Lyallpur, the total rainfall from May to December was above 8 inches in all 4 years and differences in the effects of the two levels of irrigations were non-significant throughout.

Khanewal. The differences in the effect of irrigation were non-significant in 1953–4, with a total rainfall from May to December above 8 inches. The results were significant for the next 2 years, when the total rainfall was less than 8 inches.

Multan. The total rainfall from May to December exceeded 8 inches in all 4 years and the effects of irrigation were non-significant, although the yields with six irrigations were higher than those with four.

General. In spite of the non-significance of the effects of variations in the rate of irrigation at individual stations, the overall effect was appreciable, the higher rate of irrigation giving a mean yield (15·2) which was 12 per cent. greater than that for the lower (13·6) (see Table 4, p. 41). In more normal seasons with May–December rainfall more generally below 8 inches, a more marked effect of the higher rate of irrigation is likely.

Spacing—Lyallpur. The effects of differences in spacing were significant in all years and highly so in the first three. In 3 years, 2-foot spacing was significantly the best, while in the fourth year it was not significantly different from 2·5-foot spacing. Thus on the average 2 feet was the best spacing. The 2·5-foot spacings significantly outyielded the 3-foot spacing in 3 years. The yield thus improved progressively with the decrease in spacing distance.

Wazirkot. The effect of differences in spacing was significant (highly) only in 1953–4. At this station yields were thus on the whole independent of differences in spacing.

Montgomery. The effects of differences in spacing were significant in 1953–4 and 1954–5 (highly significant); 3-foot spacing resulted in lowest and 2-foot spacing gave the highest yields throughout. The yields thus decreased with the increase in spacing distance.

Khanewal. Spacing effects were significant in 1955–6 and highly so in 1954–5, and non-significant in the other 2 years. The non-significance of the results in 1953–4 was due to 'tirak' and in 1956–7 to the attack of insect pests and diseases. These factors not only masked the effects of spacing, but reduced the level of yield as well. Two- and 2·5-foot spacings, though not significantly different, were better than 3-foot spacing. Thus in this locality also 2-foot spacing was generally the best.

Multan. Spacing effects were highly significant in 1953–4 and 1955–6 and significant in 1954–5, but non-significant in 1956–7 due to a severe attack of pests and diseases. Two-foot spacing resulted in the highest yields in 3 years, but was outyielded by 2·5-foot spacing in the other year.

General. The yield increased throughout, on the average, with closer spacing. The mean yields in maunds per acre were: 2 ft., 15·0; 2½ft., 14·4; 3 ft., 13·7. The mean yield thus decreased on the average about 5 per cent. for each increase of 6 inches in the distance between the rows (see Table 4).

Fertilizers—Lyallpur. The increases were significant in all 4 years, highly so in the first three. The use of 75 lb. N per acre gave significantly higher yields than 50 lb. in 2 years, while in the other 2 years the differences were non-significant.

Wazirkot. The increases were highly significant in the 3 years 1954–5, 1955–6, and 1956–7. In 2 years 75 lb. N per acre resulted in greater yields than 50 lb., while in the other 2 years the reverse was found.

Montgomery. Data were available for only 3 years due to canal closures. Increases were significant for only 2 years, 1954–5 and 1956–7 (highly so in the latter). 'Tirak' occurred in 1953–4. The difference in yields from 75 and 50 lb. N was non-significant.

Khanewal. Increases were significant in 2 years, 1953–4 and 1955–6 (highly significant). In the other 2 years, there was an incidence of root-rot. The effect of nitrogen was further vitiated by severe attacks of whitefly and jassids. During the years in which the effects of nitrogen were significant, the difference in the yields from 50 and 75 lb. N was non-significant.

Multan. The increases were highly significant in 3 years and significant in 1 year (1956–7). During the first 3 years there was no significant difference between 50 and 75 lb. N. In 1956–7 the crop was attacked by insects and some unknown factor caused reddening and blackening of leaves.

General. The overall effect of nitrogen was very marked. The mean yields in maunds per acre were: no nitrogen, 13·6; 50 lb. N, 14·5; 75 lb. N, 15·0. Fifty and 75 lb. nitrogen thus produced, on the average, yield increases of 0·9 (7 per cent.) and 1·4 (10 per cent.) maunds (see Table 5, p. 41).

TABLE 3. *Effects of Sowing Date on Yield of Seed Cotton at different Spacings; Rates of Irrigation; and Rates of Fertilizer Application, Maunds per acre, and (in parentheses) in Percentage of General Mean.*

Sowing Date	Spacing			Irrigations		Fertilizer application			Mean
	2 ft. (S_1)	2½ ft. (S_2)	3 ft. (S_3)	4 (I_1)	6 (I_2)	Nil (M_1)	50 lb. N (M_2)	75 lb. N (M_3)	
Early (D_1)	16·5 (115)	16·0 (111)	15·7 (109)	15·0 (104)	17·2 (119)	14·9 (104)	16·3 (113)	17·1 (119)	16·1 (112)
Medium (D_2)	15·8 (110)	15·1 (105)	14·2 (99)	14·0 (97)	16·1 (112)	14·3 (99)	15·2 (106)	15·6 (108)	15·0 (104)
Late (D_3)	12·7 (87)	12·1 (84)	11·2 (78)	11·7 (81)	12·3 (85)	11·6 (80)	12·0 (83)	12·4 (86)	12·0 (83)
Mean	15·0 (104)	14·4 (100)	13·7 (95)	13·6 (94)	15·2 (106)	13·6 (94)	14·5 (101)	15·0 (104)	14·4

TABLE 4. *Effect of Irrigation on Yield of Seed Cotton at different Spacings. Maunds per acre, and (in parentheses) Percentage of General Mean.*

Irrigations	Spacings			Mean
	2 ft. (S_1)	2½ ft. (S_2)	3 ft. (S_3)	
4 (I_1)	14·2 (99)	13·5 (94)	13·0 (90)	13·6 (94)
6 (I_2)	15·8 (110)	15·3 (106)	14·4 (100)	15·2 (106)
Mean	15·0 (104)	14·4 (100)	13·7 (95)	14·4

TABLE 5. *Effects of Rate of Fertilizer Applications on Yield of Seed Cotton at different Spacings, and Irrigations. Maunds per acre, and (in parentheses) in Percentage of General Mean.*

Fertilizer application lb. N per acre	Spacing			Irrigations		Mean
	2 ft. (S_1)	2½ ft. (S_2)	3 ft. (S_3)	4 (I_1)	6 (I_2)	
Nil (M_1)	14·2 (99)	13·6 (94)	12·9 (90)	12·7 (87)	14·5 (101)	13·6 (94)
50 (M_2)	15·2 (106)	14·7 (102)	13·5 (94)	13·8 (96)	15·2 (106)	14·5 (101)
75 (M_3)	15·6 (108)	14·9 (104)	14·6 (101)	14·3 (99)	15·8 (110)	15·0 (104)
Mean	15·0 (104)	14·4 (100)	13·7 (95)	13·6 (94)	15·2 (106)	14·4

General Discussion

Consideration of the general means for all stations (right-hand column of Table 1) shows that treatment combinations 10 to 18 inclusive form a group which resulted in the highest yields, with maxima for numbers 11 and 12. Thus, generally, the earliest dates of sowing and the higher rate of irrigation (six) resulted in the highest yields. Applications of 50 or 75 lb. N per acre, 2-foot spacing, six irrigations, and mid-May sowing at Lyallpur and Montgomery or early June sowing at Khanewal and Multan or sowing in the first week of May at Wazirkot gave the best results.

Treatment combinations 1 to 9 gave generally somewhat lower yields owing to the above-noted inferiority of the smaller number of irrigations. Treatment combinations 19 to 36 similarly gave generally lower

yields as a result of the later dates of sowing. The lowest yields were generally obtained with treatment combinations 37 to 54, in which sowing dates, irrigations, and spacing were all at the least favourable levels. The variations in yield from station to station were due to varietal differences as well as to the other factors.

Ignoring the effects of locality and varietal differences, the interrelations between the effects of sowing dates, irrigation rates, variations in spacing and applications of fertilizers are shown in Tables 3, 4, and 5 in which the interrelations of pairs of two factors are shown, with averaging out of the effects of the other two factors. Table 3 consists actually of three two-way tables for date of sowing in conjunction with spacing, irrigation, or fertilizers. Table 4 is a two-way table, irrigation and spacing. Table 5 consists of two two-way tables for fertilizer application in conjunction with spacing or irrigation.

With regard to *date of sowing*, it has already been noted that the overall effect of early sowing was to give a mean advantage of more than 4 maunds per acre over late sowing, with medium sowing somewhat less superior. Table 3 shows that these relative values were still about the same at any of the three spacings or rates of application of fertilizer or at either irrigation rate. Date of sowing may thus be taken as showing no appreciable interaction with the other treatment factors, and the superiority of early sowing as not much susceptible to modification by variations in such other factors.

The effect of different *irrigation rates* has been shown to be largely masked by abnormally high rainfall in the four seasons during which these experiments were carried out, so that the overall mean advantage of six irrigations over four was only about 1½ maunds per acre. Tables 3, 4, and 5 show that this advantage was fairly constant regardless of different spacings or rates of fertilizer application, but that the superiority of the higher rate of irrigation was considerably greater for crops sown at early or medium dates (about 2 maunds) and much less (0·6 maund) for late-sown crops. These results are of practical value in indicating that additional irrigation is generally unlikely to be worth while for late-sown cotton and that the water could probably be used to better advantage on other cash crops such as sugar-cane or tobacco.

The overall mean effect of *differences in spacing* was a progressive loss of 0·6 or 0·7 maunds per acre for each increase of 6 inches in the distance between the rows. Tables 3, 4, and 5 show indications of interaction of spacing with sowing date, irrigation rate, and application of nitrogen, in the sense that, while there was little apparent effect of variations in the level of any of these three factors on the fall in yield at 2½-foot spacing below that at 2-foot spacing, the further widening of spacing to 3 feet was associated with losses of yield in excess of the above mean rate, for the later planting dates, the higher rate of irrigation, and the application of nitrogen, although the individual figures are somewhat erratic. While closer spacing is in general advantageous, the benefits tend to be highest under less favourable conditions, e.g. limited water supply or late sowing. There are indications of a second-order interaction between spacing, irrigation, and sowing date, whereby at the lower irrigation rate the

advantage in yield from close (2 foot) spacing for late-sown cotton is twice that for the early-sown crop.

The overall mean effect of the application of 50 or 75 lb. N per acre, as ammonium sulphate, has already been noted, the resulting increases in mean yield of seed cotton being 0·9 and 1·4 maunds per acre respectively. From Tables 3 and 5 there are fairly clear indications of a marked interaction of sowing date, spacing, or irrigation, on the effect of nitrogen, especially at the 50 lb.-per-acre rate, in the sense that the response to nitrogen was progressively lower for the later sowings, lower for the widest spacing and for the higher rate of irrigation (although the effect of the increase from medium to wide spacing on the response to the increase from 50 to 75 lb. N per acre does not conform). Taking the prices of ammonium sulphate and seed cotton at approx. 12 and 30 rupees[1] per maund respectively, it would appear that for early-sown cotton the application of 50 lb. N per acre was quite profitable, and that of 75 lb. even more so, whereas for cotton sown at the medium date the profit from the use of 50 lb. N per acre was only slight, and increase from 50 to 75 lb. N was completely unprofitable, and for late-sown cotton both rates of application of nitrogen were wholly uneconomic.

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[1] rupee = 1*s.* 6*d.*

THE NGUNI BREED OF CATTLE
II. MORTALITY, GRAZING BEHAVIOUR, AND BEEF PRODUCTION

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Summary

Mortality. Of all calf deaths at Mpisi (1946 to 1950), most were caused by heartwater, 'poverty', and sweating sickness, followed by plant poisoning, pneumonia, snake-bites, and redwater. Nguni calf mortality was approximately 7 per cent. of all live births.

Of a total of 1,100 Ngunis at Mpisi, 8·1 per cent. died compared with 13·8 per cent. of a total of 94 crossbreds.

Grazing behaviour. Animal behaviour observations were conducted on five cows (with calves) each on a different day, and on a group of four cows (and calves) for periods varying from 7 to 11 hours. A sense of smell appears to play a part in grazing and an apparent selectivity was noticed while grazing in long grass. No relationship between wind direction and grazing direction was apparent. Whether there was a large or small group of cows, the individuals comprising the group would remain in close proximity. Defaecation and urination in watering places was noticeable especially when temperatures were over 80° F. Suckling ensued once daily while in the camp and maternal affection is strong. It is concluded that with not less than four cows and their calves a herd-grazing pattern is manifested.

Water consumption per cow and calf varied from 3½ gallons (overcast—max. atmospheric temperature 68·0° F.) to 5 gallons daily (max. atmospheric temperature 85·2° F.).

Beef production. Seventy-five Nguni oxen were sent to Johannesburg for slaughter. Forty-eight of the carcasses were graded as Prime, twenty-six as Grade I, and one as Super. The grader's reports indicated that the cattle lacked fullness in the hindquarters, and were deficient in fleshing qualities in the forequarters.

It is concluded that these characteristics are primarily attributable to the genotype rather than the environment, and that by a breeding policy with selection for beef quality and early maturity, coupled with improvement in grazing management and watering, Nguni oxen could be marketed at under 4 years old and still obtain the better grades. But in the native areas the chief limiting factor is adequate provision of nutrients and water, and the level to which the beef potential of the oxen can be usefully raised by breeding is determined by the degree of improvement in feeding and management.

Mortality

THE number of deaths, and their causes, were extracted from records kept on the Mpisi Experimental Station in the Middleveld region of Swaziland. The period covered is from February 1946 to the end of December 1950, firstly for calves, and secondly for all Nguni and cross-bred cattle. Table 1 shows that heartwater, 'poverty', and sweating sickness accounted for most of the deaths of all calves born alive at Mpisi. To combat heartwater, all calves at Mpisi are inoculated before

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the age of 3 weeks. Other deaths of calves were caused by poisoning (plant and mineral), pneumonia, and various other factors.

TABLE 1. *Mortality of Nguni and Afrikaner × Nguni (F1) Calves at Mpisi, 1946 to 1950*

% T.C. = per cent. of total calves (approx.)
% T.C.D. = per cent. of total calf deaths (approx.)

	Nguni calves			*Crossbred calves*		
Cause of death	*No.*	*% T.C.*	*% T.C.D.*	*No.*	*% T.C.*	*% T.C.D.*
Poverty (poor condition)	7	1·4	21	1	1·1	11
Sweating sickness	4	0·3	12	..	..	..
Poisoning	3	0·6	9	2	2·2	22
Suspected botulism	1	0·2	3	..	..	..
Suspected heartwater	9	1·8	27	1	1·1	11
Red Water	..	..	..	2	2·2	22
Gallsickness	1	0·2	3	..	..	..
Quarter evil	1	0·2	3	..	..	..
Snake bite	1	0·2	3	1	1·1	11
Pneumonia	3	0·6	9	1	1·1	11
Haemorrhage	2	0·4	6	..	..	..
Miscellaneous	1	0·2	3	1	1·1	11
Total	33	6·6	100	9	10·0	100

Ogilvie [1], working with the Tharparker and Sahiwal breeds in India, recorded a calf mortality of 7 per cent., which is similar to the above figure for Nguni calves.

In the native areas of Swaziland and Zululand, calf mortality is exceedingly high [2]. Of the total number of Ngunis (1,100) introduced into or born at Mpisi over the period under review, eighty-nine died from known or suspected causes. Of the ninety-four crossbred Afrikaner × Nguni, thirteen died. Table 2 lists the causes of death.

The mortality of the crossbred group was thus higher than that of the Nguni group, but in view of the small number of crossbred animals no firm conclusions can be drawn. Of the twenty-two deaths recorded under 'poverty', the great majority were of calves, although old age also accounted for many. Barnard [3] attributes this calf mortality to dams that were unable to feed their calves.

Regarding the Ngunis' resistance to diseases, the Report of the Committee of Investigation [2] states: 'these cattle have through natural selection developed certain hereditary characters which offer a greater degree of resistance to infection by diseases such as heartwater, redwater, trypanosomiasis, ophthalmia, etc.' The resistance of the Zulu (Nguni) to tick-borne diseases had been previously observed by Curson [4], while Bonsma [5] indicated hereditary heartwater-resistant characters in the Afrikaner. There seems to be little support for the opinion that the Nguni has any noticeable measure of resistance to trypanosomiasis [6, 7].

TABLE 2. *Mortality of Nguni and Afrikaner × Nguni (F1) Cattle at Mpisi 1946 to 1950*

% T.P. = per cent. of total population
% T.D. = per cent. of total deaths

Cause of death	*Nguni cattle*			*Crossbred cattle*		
	No.	*% T.D.*	*% T.D.*	*No.*	*% T.P.*	*% T.D.*
Poverty (poor condition)	22	2·0	24·7	1	1·1	7·7
Sweating sickness	4	0·4	4·5	..	..	..
Poisoning—arsenic and plant	8	0·7	9·0	2	2·1	15·4
Suspected botulism	1	0·1	1·1	..	..	..
Suspected heartwater	12	1·1	13·5	1	1·1	7·7
Red water	3	0·3	3·4	2	2·1	15·4
Gallsickness	4	0·4	4·5	2	2·1	15·4
Quarter evil	2	0·2	2·3	..	..	..
Snake-bite	6	0·6	6·7	1	1·1	7·7
Septicaemia	2	0·2	2·3	..	..	..
Pneumonia	4	0·4	4·5	1	1·1	7·7
Haemorrhage	2	0·2	2·3	..	..	..
Lumpy skin	2	0·2	2·3	..	..	..
Destroyed (accidents)	9	0·8	10·1	1	1·1	7·7
Dystokia	3	0·3	3·4	..	..	..
Miscellaneous (shock, enteritis, tumour, and undiagnosed)	5	0·5	5·6	2	2·1	15·4
Total	89	8·1	100·0	13	13·8	100·0

The Behaviour of Nguni Cows and Calves during Diurnal Grazing

A preliminary investigation into the herd behaviour of Nguni cows of the milk herd was carried out at the Mpisi Experimental Station in Swaziland. The obervation periods extended from 7 to 11 hours. Atmospheric temperature and humidity were measured hourly by a standard thermometer and a sling hygrometer.

Five Nguni cows (with calves), being part of a group of eight, were kept under observation, each cow being followed separately (on different days), from the time they were turned out each morning until they returned to their night paddock. Approximate distances walked, maternal behaviour, grazing and drinking statistics, time spent in the shade, rest periods, rumination periods, and number of defaecations and micturitions were all recorded.

In addition to these observations on single cows, an 11-hour observation was kept on a small group of cows (almost dry), and their offspring, in a small paddock of 8 to 10 acres. After the animals had become familiar with their new surroundings, records were kept of atmospheric temperature and relative humidity as well as the other observations mentioned above.

An estimate was made of the average daily water requirement for each cow and calf. Measurements, corrected for leakage and evaporative losses, were made from a concrete trough. Grazing conditions were

fair to good and the grass was green and fairly succulent over the two water-consumption trial periods.

Appendix, Table 4, presents the combined observations on the five Nguni cows each observed on a different day.

By making use of the small paddock the observations in Appendix, Table 5, were recorded on four cows and their calves.

From these observations on grazing behaviour the following points were noticed. A certain amount of browsing was observed when the cows would 'pick off' the pods especially from the *Dichrostachys glomerata* bushes. The number of cropping movements per minute remained relatively constant for each animal throughout each period of observation and no discernible 'slackening off' effect due to fatigue was noticed during the late afternoon. A sense of smell apparently plays a major part during the grazing since the eyes were frequently diverted by distractions elsewhere while grazing continued and an apparent selectivity was exercised in long grass. Where the grass was short, no apparent selectivity seemed to be exercised. Johnstone-Wallace in his *Grazing Habits of Beef Cattle* [8] states: 'behaviour indicated that the sense of smell largely determined the herbage gathered—[they] were, in fact, constantly smelling herbage before selecting.'

No apparent relationship between direction of grazing and wind direction would seem to exist: the herd, in each of the observations carried out in the large camps at Mpisi, tended to graze in a clockwise direction in a large circle, round part of the camp. The point of entry of the herd to the camp, the lie of the land as regards undulations, and the amount of grass-cover appear to influence direction of grazing. It was noticed that the polled cow (S.G. 350) was continually 'worried' out of the 'grazing-lines' of the horned cows. Hancock [9] terms this the 'ranking order'.

Another point of interest mentioned by Hancock [9] is the strong 'herd laws' which exist among cattle. This was noticeable in the Nguni milk herd where this gregarious habit tended to keep the individuals comprising the herd in close proximity. In this connexion it was observed that the herd peacefully grazing at one moment would be restless the next, and would begin alternately grazing and walking, *en route* to the watering place. It was also noticed that a low-sounding type of bellow, perhaps from a thirsty cow, appeared to cause this agitation.

Defaecation and urination into drinking water (in shallow dams) frequently occurred, the cattle seemingly having no regard for their water-sources. It was noticed that when high temperatures (over 80° F.) prevailed, the incidence of water-soiling increased, mainly because the animals tended to stand in the water for a longer period than usual.

Apart from the initial suckling prior to milking, the 4-to-6-month-old calves suckled only once during the periods of observation, and then mainly at about 10 to 11 a.m. Most of them consumed water with the rest of the herd. Maternal affection appeared to be strong and cows often played with their offspring.

Nguni cows moved their ears vigorously when flies irritated in the region of the head. Ears were used independently or together. The

flexible and long tail with a well-developed switch also materially assisted in removing irritating insects.

The four cows and calves observed together in a small paddock still appeared to adhere to a herd-pattern in their grazing, and when one animal rested in a corner of the paddock, the other three seemed reluctant to graze very far away. Cows were seen to graze right up to the fence together and resumed grazing within a few minutes of each other. Calves frequently rested and ruminated several times during the day, while their dams grazed in close proximity. A slight degree of herbage selection was noticed and sense of smell appeared to have a great deal to do with selection from the manner in which the grass was 'muzzled'.

This latter observation period might serve as a guide for future investigations into Nguni grazing behaviour, using at least four (preferably more) cows and their calves to give an indication of 'herd' behaviour. Harker *et al.* [10], in observations on the grazing habits of Zebu cattle, found that in each 24-hour period, 7·7 hours were spent in grazing; 93 per cent. of the grazing occurred during the 12 hours of daylight; 5·2 hours were spent in ruminating and 23 per cent. of this time was during the hours of daylight. This is contrary to the findings of Seath and Miller [11] who observed a greater percentage of the grazing being effected at night when temperatures were high during the day.

With regard to water consumption, cows in milk, plus their calves (about 4 months old), averaged approximately 5 gallons daily over a period of 6 days (May 1951). During October 1951, on a fairly warm day (max. 85·2, min. 57° F.) the four cows and their calves consumed 35 gallons, or an average of approximately 8¾ gallons per cow and calf (9–10 months old). On an overcast day (max. 68·0, min. 61·7° F.) the average daily consumption per cow and calf was 3½ gallons. On this occasion the grass was quite damp from dew.

The importance of supplying adequate amounts of water (cool if possible) to cattle in warm climates 'would constitute a very potent method for body heat dissipation in these slightly sweating animals' (i.e. Jersey and Holstein cows) [12]. Payne and Laing [13] support this conclusion and say 'a high water consumption is one of the more important methods of temperature control utilised by dairy cattle in the tropics'.

The Nguni as a Beef Producer

Seventy-five Nguni oxen, bred and reared on the Mpisi Experimental Station in Swaziland, were sent by road and rail (a distance of about 250 miles, taking 1½ to 2 days) to the Johannesburg abattoir in June 1951 and March 1952 as trial shipments. Owing to the recent start of crossbreeding programmes, only two crossbred oxen (F1) were sent. The Chief Government Meat Grader carried out the grading, and commented on each carcass. These results and comments are arranged in 3-month age groups, the means being given in Table 3.

The oxen had been taken straight off the veld; they were weighed before shipment and again on arrival at the abattoir. The dressed weight and approximate dressing percentage for each animal was also recorded.

The grading takes into account the age of the animal as well as the condition of the carcass, which largely reflects nutritional conditions. The position of each carcass within the grade was also indicated.

TABLE 3. *Mean Live and Dressed Weights of Nguni Oxen sent to the Johannesburg Abattoir in June 1951 and March 1952, by Age Groups*

1st wt. = weight before transit; 2nd wt. = weight before slaughter.
W.D. wt. = warm dressed weight.

Age group, months inclusive	*No. in group*	*1st wt. lb.*	*2nd wt. lb.*	*Shrinkage %*	*W.D. wt. lb*	*Offal wt. lb.*	*Hide wt. lb.*	*Dressing percentage*
47–49 .	5	1,005	866	13·8	484	318	63	55·7
50–52 .	27	996	882	11·4	509	308	64	57·9
53–55 .	18	1,010	927	8·7	535	321	67	58·0
56–58 .	9	1,025	932	8·8	548	319	65	58·9
59–61 .	7	982	870	11·4	512	294	63	59·1
62–65 .	8	1,190	1,054	11·4	640	337	75	59·9
72 . .	1	1,356	1,230	9·3	734	410	86	59·7

As is to be expected, dressing percentage varied with age [14]; the mean increased from 56 for the 47–49-month age group to 60 for the 56–58-month age group.

The 47–49-month group had 100 per cent. Grade 1, which in view of their age would appear to reflect their lack of finish. Unfortunately, no report was issued for these animals to confirm these suspicions.

The 50–52-month group had 56 per cent. Prime C, 37 per cent. Grade 1, and 7 per cent. Prime B. A report on 10 of these oxen indicated that the quality and finish were 'fairly good' to 'good'. The criticism passed on two of them was that there was room for improvement in the loin region, and in the forequarters in one case.

In the 53–55-month group 56 per cent. fell in the Prime C grade, 33 per cent. in Grade 1, and 11 per cent. in Prime B. Again quality and finish were 'fairly good' to 'good'. The criticism of these animals was that they lacked fullness in the region of the loin and buttocks, and in the hindquarters in general. Out of the eighteen oxen, nine were criticized for lack of fullness in the forequarters, and one for uneven fat covering.

In the 56–58-month group, 66 per cent. were graded as Prime C, while the remainder fell into Grade 1. Quality and finish were very much the same as the preceding classes, and again the loin, buttocks, and forequarters were criticized for being deficient in flesh.

In the 59–61-month group, 86 per cent. were Prime C and 14 per cent. Grade 1. Quality and finish were similar to those of the previous classes, and criticisms as for the previous group.

In the 62–65-month group, 75 per cent. were Prime C, 12½ per cent. Super C, and 12½ per cent. Grade 1. The same remarks as for the previous groups applied here.

The two crossbred oxen were graded Prime B and Prime C, and were reported to be 'good' as far as quality and finish were concerned.

To sum up, out of 75 Nguni oxen sent to Johannesburg, 48 were graded as Prime, 26 as Grade 1, and 1 as Super. The general complaints were that the cattle lacked fullness of the loin, rump, and buttocks (i.e. the hindquarters generally) and were deficient in fleshing qualities in the forequarters. Considering that the veld at Mpisi before June 1951 and March 1952 can be classified as being fair to good, the criticisms applicable to these animals can, in fact, be attributed mainly to inheritance, with climate a secondary consideration. Thus it would appear that, to overcome these undesirable features, a careful breeding policy would have to be followed to build up a Nguni beef type. It seems not unlikely that, with such selection for beef quality and early maturity, coupled with improvement in the management of grazing and watering facilities, and with provision for the dry periods, Nguni oxen could in time be marketed at under 4 years of age and still obtain the better grades. However, the effect of climate must be taken into account in such a breeding programme.

The chief limiting factor for increased beef production with the Nguni in Native areas is adequate provision of nutrients and water. Without this it would appear purposeless to improve the Nguni beyond a certain stage for beef production. Hence the advisability of breeding up to the level of the environment and then improving this level wherever possible, with a corresponding improvement in the genotype [15].

In favour of the Nguni as a beef producer, it is noteworthy that Mashona steers (a Sanga type) in Southern Rhodesia, under free-range conditions on a European-owned farm, have been reported to have an average cold dressed weight of 520 lb. off the veld at the age of $3\frac{1}{2}$ years. They are a small-boned breed with a good beef conformation [16].

Strict selection for a beef-type conformation together with an overall improvement in grazing and watering facilities is recommended.

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Appendix

TABLE 4. *Observations on Five Nguni Milk Cows, Each Observed on a Separate Day*

S.G. no. / *Colour*	*316* *Black Nkone*	*72* *Red Nkone*	*94* *Nhlo-pekati*	*89* *Mpunga Strawberry*	*350* *Black Nkone*
Date of observation	26.4.51	3.5.51	4.5.51	7.5.51	15.5.51
Period of observation, hours	7	7½	8	8	8
Age of cow (years)	10	10	9	10	4 yrs. 4 mths.
Calved on	5.11.50	3.11.50	19.11.50	7.11.50	7.1.51.
Weight of cow at start (lb.)	732	819	856	916	760
Estimated distance walked (miles)	1½	2	1⅒	1½	1
Total time grazing (mins.)	250	360	310	365	370
Time grazing in shade (mins.)	12	1	13	2	6
Browsing time (from bushes) (mins.)	3½	1	21	1	..
Loafing time (mins.):					
(*a*) standing	27	57	39	7	..
(*b*) lying	15	..	20	20	..
Time of day cow loafed (longest single period)	11.05	11.10	11.30	12.50	..
Time ruminating (mins.):					
(*a*) standing	..	35	30	24	4
(*b*) lying	60	..	..	20	81
No. of jaw movements before deglutition (mean)	46–51	55–66	37–57	51–55	46–55
Period between ascent and descent of bolus (secs.)	49–55	50–65	50–75	50–53	50–61
Time of day cow started ruminating	11.10 a.m.	11.27 a.m.	12.30 p.m.	12.17 p.m.	11.02 a.m.
Mean time between descent and ascent of bolus (secs.)	4	4	4	4	3
Total time spent in shade (mins.)	12	1	34	65	±6
No. of cropping movements (grazing) per minute	48–64	46–67	31–65	36–64	36–39
No. of times suckled calf	1	1	1	1	..
Time suckling calf (mins.)	4½	13	12	7	..
Time of day calf was suckled	10.45 a.m.	11.20 a.m.	2.54 a.m.	10.05 a.m.	..
Number of defaecations	5	4	6	6	5
Number of micturitions	3	6	2	7	4
Number of drinks	1	1	1	nil	1
Time spent drinking (mins.)	3	3½	3	..	1½
Time of day cow watered	2.15 p.m.	1.15 p.m.	9.26 a.m.	..	8.42 a.m.
Temperature range °F.	66·4–82·0	67·5–80·5	67·0–92·0	67·0–87·0	61·5–80·5
Relative humidity range %	43·0–68·2	45·2–73·0	23·0–70·0	43·4–90·0	43·4–90·0
Percentage of period grazing	60	80	65	76	77

TABLE 5. *Results of Observations on Four Nguni Cows, 15 October 1951*

S.G. no. / *Colour*	*15* *Straw-berry*	*23* *Inca-wana*	*102* *Red Nkone*	*117* *Black Nkone*
Age of cow (years)	11	7	11	10
Age of calf (months)	10	11½	11	11
Weight of cow at start (lb.)	847	695	762	685
Estimated distance walked (miles)	⅞	⅞	¾	¾
Total time grazing (mins.)	510	475	460	465
Time grazing in shade (mins.)	3	..	9	..
Loafing time (mins.):				
(*a*) standing	86	126	85	110
(*b*) lying	18	..	40	35
Portion of loafing-time spent playing with and licking calf (mins.)	34	20	25	58
Time of day cow loafed (longest single period)	Between 7 and 9 a.m.			
Time ruminating (mins.):				
(*a*) standing	32	66	40	45
(*b*) lying	49	35	66	34
Times of day cow started ruminating	All cows approx. 7–12 a.m., 12.41 p.m., 1.47 p.m., and 6.25 p.m.			
Total time spent in shade (mins.)	25	108	46	40
No. of cropping movements (grazing) per min.	51–52	50–55	48–55	44–53
No. of defaecations	5	9	8	4
No. of micturitions	2	1[1]	4	1[1]
No. of drinks	2	2	2	2
Time spent drinking (mins.)	3	3	5	3
Time of day cow watered	All animals 10.56 a.m. and 3.02 p.m.			
Percentage of 11-hour-day grazing	77	72	70	71

[1] It is possible that a second micturition was unobserved.

MANURING OF GREEN CROPS USED IN TEA CULTURE

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Summary

Leguminous green crops are used in tea estates to rehabilitate areas from which tea has been uprooted for replanting and also in young and poor mature tea areas where the tea has not covered the ground adequately and has not got sufficient shade.

In the experiment under reference, three levels of phosphorus and potassium, and two levels of calcium, and their combinations were applied to a green crop of *Crotalaria anagyroides* that was sown in an area of land cleared and one year prior to planting up with tea.

It has been found that application of 80 lb. of P_2O_5 per acre as superphosphate was most beneficial to the green crop. This application was made by drilling in 1 lb. of superphosphate in every 40 running feet of the rows of green crop, the rows being 2½ feet apart. It has also been observed that an addition of 40 lb. K_2O to the 80 lb. of P_2O_5 per acre increased the yield of seed whilst having no significant effect on the weight of green matter.

MOST agricultural legumes benefit from application of phosphatic fertilizers regardless of the amount of phosphorus available in the soil. Much has already been done to examine the use of phosphorus in various places, in many differing soils, and in relation to a variety of crops.

Favourable yield responses of legume fodders to phosphatic fertilization have been reported [1, 2, 3, 4, 5]. It has been found that an increase in the level of soil phosphorus tended to produce large dry-matter yield in legumes [6]. Beneficial effects of superphosphate on green crops on tea estates have been reported [7, 8]. Others [9] working under Hyderabad (India) conditions have shown that the application of phosphorus to the green manure crop *Crotalaria juncea*, when grown on a well-drained red sandy loam soil previously cropped to maize, with an available 50 lb. of P_2O_5 per acre, had no beneficial effect in increasing the production of green matter.

Child *et al.* [10] found a highly significant response to phosphorus application at the rate of 30 lb. P_2O_5 per acre in Napier Grass. No significant responses were obtained to potassium and lime. As reported in *The Annual Report of Tea Research Institute of East Africa* [11], when tea was grown on the same soil as that used by Child *et al.* [10] there was no response to phosphorus. This showed that Napier Grasses gave no indication of the phosphorus needs of tea in the same land.

Crotalaria anagyroides is one of a large group of Crotalarias which can be used with periodical lopping, as a green crop for 2 or even 3 years in tea. It thrives well on poor soils and can suppress and eliminate weeds such as *Eupatorium odoratum*, *Imperata arundinacea*, *Panicum plicatum*,

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&c. It is valuable in tea: (1) because it carries root nodules, and it gives nitrogen in the tea areas; (2) it can be used for green cropping and weed extermination on land lying fallow before planting; (3) as a green crop in poor mature tea; (4) as a green crop and shade for young tea; (5) as a green crop in tea-seed nurseries; (6) as a green crop in tea at high altitudes; (7) for rehabilitation of uprooted or poor-soil tea areas [12]; and (8) for growing on waste land for production of mulch.

The object of the experiment here reported was to study the effect of levels of phosphorus, potassium, and calcium and their combinations when applied to the green crop *Crotalaria anagyroides*, and, subsequently, the joint residual effects of fertilizer and green crop on the growth of young tea, planted after incorporating the green crop in the soil. The present paper refers only to the first phase of the experiment.

It should be noted that tea soils are characteristically acid, and the soils of this area of the Borbhetta Experimental Garden, where the experiment was conducted, have a pH of 4·70 with 90 lb. of available P_2O_5 per acre.

Experimental Details

The green crop *Crotalaria anagyroides* was sown at the end of April 1957 in rows 2½ feet apart on sandy loam soil. During the week of sowing 3·48 in. of rain was recorded. From May to December 1957 the distribution of rainfall was fairly good (Appendix). The plants were thinned out to one plant every 6 in. spacing when 6 in. high. Superphosphate and sulphate of potash were applied 1 week before sowing the green crop, and slaked lime was applied 3 weeks before. The manures were applied in a 1-foot band along each row and incorporated in the soil by light hand forking. Out of seven rows of green crop per plot, four alternate rows were uprooted at the end of February 1958 and tea was planted in April 1958 in those lines for the study of residual effect. All the green matter produced was returned in the respective row of the plot.

The plots, which were 20 × 44 feet in size, had seven rows of green crop and were arranged in four randomized blocks each having eighteen treatment plots. Each plot will have four rows of tea and forty bushes in the centre two rows will make the experimental area of tea. Each plot was separated along the sides from adjacent plots by an unmanured row of green crop. At the ends of the rows 2-foot guard strips were left.

The treatments were three levels of phosphorus and of potassium and two levels of calcium, and their combinations, making eighteen treatments in all.

Superphosphate . . .	P_0	No P_2O_5
	P_1	40 lb. P_2O_5 per acre
	P_2	80 lb. P_2O_5 per acre
Sulphate of potash . .	K_0	No K_2O
	K_1	40 lb. K_2O per acre
	K_2	80 lb. K_2O per acre
Slaked lime . . .	Ca	No lime
	Ca_1	328 lb. slaked lime per acre

In the course of the study, observations were taken on height of plants, plant samples were drawn for weight of shoots and roots in the last week of July 1957 and last week of November 1957, weight of loppings at 3 feet height in the first week of August 1957, weight of loppings of three rows at $3\frac{1}{2}$ feet, and total weight of plants of four rows cut at ground level during February 1958, weight of seeds collected in the third week of January 1958, and total weight of green matter of the green crop added to the plot.

Results

Growth Characters—Green Crop 3 months old.

The responses in growth characters to both the dressings of phosphorus were significantly beneficial as shown in Table 1. Increasing doses of phosphorus increased the height, weight of shoots and roots, and weight of loppings cut at 3 feet height. The double dose of phosphorus gave approximately twice as big an increase in loppings and in weight of plant (shoots and roots) as did the single dose. For plant height, however, the single dose was nearly as effective as the double dose.

TABLE 1. *Height, Weight of Shoots, Weight of Roots, and Weight of Loppings at 3 feet from the Ground, of* Crotalaria anagyroides *Plants at the Age of 3 months under Different Levels of Phosphorus*

Treatments	*Mean height in inches*	*Mean weight per plant in gm.*		*Mean weight of loppings per plot in kilogrammes*
		Shoots	*Roots*	
P_0—no phosphorus . .	20·6	29·6	3·8	0·9
P_1—40 lb. P_2O_5 per acre . .	42·0	66·4	9·0	12·6
P_2—80 lb. P_2O_5 per acre . .	46·9	111·6	14·2	22·3
Least Significant Difference (P = 0·05)	5·0	29·8	4·3	4·5

The application of lime only, increased the lopping weights.

TABLE 2. *Height, Weight of Shoots, Weight of Roots, and Weight of Loppings at 3 feet from the Ground, of* Crotalaria anagyroides *Plants at the Age of 3 months under Different Levels of Calcium*

Treatments	*Mean height in inches*	*Mean weight per plant in gm.*		*Mean weight of loppings per plot in kilogrammes*
		Shoots	*Roots*	
Ca_0—no lime	35·0	67·3	8·7	8·6
Ca_1—328 lb. slaked lime per acre	38·0	71·1	9·3	15·2
Least Significant Difference (P = 0·05)	Not significant			3·7

The overall effect of potassium failed to produce any significant effect on the growth characters at this stage.

TABLE 3. *Height, Weight of Shoots, Weight of Roots, and Weight of Loppings at 3 feet from the Ground of* Crotalaria anagyroides *Plants at the Age of 3 months under Different Levels of Potassium*

Treatments	*Mean height in inches*	*Mean weight per plant in gm.*		*Mean weight of loppings per plot in kilogrammes*
		Shoots	*Roots*	
K_0—no K_2O	33·0	53·0	6·7	10·0
K_1—40 lb. K_2O per acre . .	37·6	77·7	10·4	14·4
K_2—80 lb. K_2O per acre . .	38·9	76·9	9·7	11·3
Least Significant Difference (P = 0·05)	Not significant			

The interaction of Ca × P × K was significant for the weights of shoots and roots. $Ca_1P_2K_2$ produced the highest shoot weight, closely followed by $Ca_0P_2K_1$, whereas $Ca_0P_2K_1$ produced the highest weight of roots. In the weight of loppings the differences due to the interaction combination of calcium × phosphate and phosphate × potash were significant. The highest weights were from Ca_1P_2 and K_1P_2 respectively.

Weight of Shoots and Roots at the Age of 7 months

Only the effects of different levels of phosphorus were significant for shoot and root weights of plants. For weight of shoots 40 lb. and 80 lb. P_2O_5 were significantly higher than no phosphorus but there was no significant difference between the two doses. For weights of roots, only 80 lb. P_2O_5 per acre produced significantly higher weights over no phosphorus (Table 4).

TABLE 4. *Weight of Shoots and Roots of 7-months-old* Crotalaria anagyroides *Plants under Different Levels of Phosphorus*

	P_0	P_1	P_2	*Least Significant Difference* (P = 0·05)
Mean weight of shoot per plant in gm.	300	473	516	108
Mean weight of roots per plant in gm.	25·2	32·7	39·5	8·6

Weight of Last Loppings

Different dressings of phosphorus produced highly significant effects on lopping weights of three rows cut at $3\frac{1}{2}$ feet above ground and four rows cut at ground level. The increasing levels of phosphorus increased the green matter.

Application of phosphorus significantly increased the weight of total green crop cut during the season and applied in the field (Table 5). The higher level of phosphorus was more effective in production of green matter.

TABLE 5. *Lopping Weights of Green Crop under Different Levels of Phosphorus*

	P_0	P_1	P_2	*Least Significant Difference* (P = 0·05)
Weight of the loppings at the age of 7 months in lb.	3,501	6,348	7,682	730
Total green matter lopped in lb. .	3,534	6,847	8,562	843

Weight of Seed

Different doses of phosphorus produced no marked difference in the weight of seed harvested but both the levels produced significantly higher yields than no phosphorus. The effect of the P × K interaction was significant. P_2K_1 produced the highest yield of seed and was significantly higher than all the combinations except P_1K_0 (Table 6).

TABLE 6. *Weight of Seed in lb. from Different Levels and Combinations of Phosphorus and Potassium*

Phosphorus \ *Potassium*	K_0	K_1	K_2	*Total*
P_0 . . .	8·44	9·19	12·06	29·69
P_1 . . .	18·44	15·81	16·75	51·00
P_2 . . .	15·50	20·56	16·38	52·44
Total .	42·38	45·56	45·19	133·13

Least Significant Difference (P = 0·05) between levels of P or K = 6·34.
Least Significant Difference (P = 0·05) between individual figures = 3·66.

Discussion and Conclusion

The application of superphosphate had a pronounced effect on the growth of the green crop *Crotalaria anagyroides*. This supports the views as reported by Andrews [7] and Cooper [8] and is contrary to the findings of Desai *et al.* [9].

As the level increased from 40 to 80 lb. P_2O_5 per acre the growth also increased. When the plants were 3 months old, increasing levels of phosphorus increased the height of plants, weight of shoot and root of the green crop as well as weights of loppings cut at 3 feet height. At the time of flowering when plants were 7 months old, phosphorus maintained its beneficial effect on the growth characters. Its effect was also prominent on the weight of loppings, but not so pronounced as noticed in the early stages. This showed that phosphorus had more effect on the growth of the green crop at an early stage than at maturity and this was certainly not due to lack of moisture in the soil.

It was reported [13] that a heavy dose of phosphorus as superphosphate alone produced better results in the health and growth of leguminous trees. The same was true with the leguminous green crop

Crotalaria anagyroides. It was evident from this study that the application of superphosphate alone to this green crop at the rate of 80 lb. P_2O_5 per acre, i.e. 1 lb. of superphosphate drilled in 40-foot rows $2\frac{1}{2}$ feet apart, was beneficial. When seed was also harvested from the green crop the mixture of 80 lb. P_2O_5 and 40 lb. K_2O per acre also proved more productive.

At the age of 3 months, calcium as well as the combinations of calcium and phosphorus, and of phosphorus and potassium, increased the yield of the loppings. But when plants attained the stage of maturity calcium failed to show any significant effect. The overall effect of potassium on the green crop was not significant throughout the period of study.

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APPENDIX

Monthly Distribution of Rainfall in Inches during 1957–8

April	1957	5·91
May	1957	26·54
June	1957	12·68
July	1957	16·15
August	1957	11·27
September	1957	6·27
October	1957	4·88
November	1957	2·04
December	1957	0·45
January	1958	0·36
February	1958	1·58
March	1958	0·40

THE EFFECT OF FERTILIZERS ON THE YIELD AND QUALITY OF GROUNDNUTS IN SIERRA LEONE

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Summary

The only fertilizers at present necessary to improve the yield of groundnuts in Sierra Leone are those containing calcium, potassium, and magnesium. The last two elements are beneficial to the plant as a whole whilst calcium is especially effective in improving the shelling percentage, i.e. reducing the number of 'pops'. Increases in yield obtained with superphosphate have been due to its calcium content.

Two hundredweights of superphosphate per acre has been the recommended fertilizer dressing for groundnuts in Sierra Leone for some years, and spectacular increases in yield have been reported [1, 2]. The soils used for groundnut production are of low inherent fertility, being strongly acid (pH 4·5–5·2) and severely leached, and the probability of widespread nutrient deficiencies was recognized [2]. The experiments reported here were carried out to discover these deficiencies and to find means of correcting them.

Review of Literature

The response of groundnuts in Africa to fertilizers has been recently reviewed by Oram [3] whilst the older work was thoroughly covered by Harris and Bledsoe [4] and York and Colwell [5]. In the U.S.A. there is general agreement on the value of added calcium but in Africa reports of calcium deficiency are rare. Roche *et al.* [6] have shown small yield increases resulting from the use of lime in Madagascar, whilst in Nigeria the value of gypsum lies in its sulphur content rather than calcium [7]. Nitrogenous fertilizers have been reported as highly beneficial by Oram [8] and superphosphate by Nye [9]. In view of the size of the African continent and the considerable variations in soil parent material and climate involved, it is not surprising that response to fertilizers varies from region to region.

In Sierra Leone the value of superphosphate for a number of crops has long been recognized but positive results from other fertilizers have been noted only occasionally although leaf symptoms of nitrogen, potassium, and magnesium deficiencies are by no means rare. Small, but non-significant, increases in the yield of yams using ammonium and potassium sulphates occurred at Njala whilst ground oyster shells improved the yield of swamp rice at Waterloo in 1949 [10]. Ammonium sulphate was found to be beneficial to guinea grass but caused a reduction in groundnut yields at Njala in 1951 [1] whilst potassium sulphate improved cassava yields at the same site in 1952 [2]. Numerous negative results have been reported.

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Preliminary Work

Pot experiments were carried out during 1953 to discover the response of groundnuts to additions of all known plant nutrients both singly and in combination. During 1954 a 2^8 factorial field experiment was laid down to confirm the results obtained. A brief report of this has been made [11] but germination was so bad that it was impossible to determine the optimum combination of fertilizers with any precision, although it was shown that neither sodium borate nor sodium molybdate had any effect on the crop even at the high rate used. Superphosphate, potassium sulphate, lime, manganese sulphate, and magnesium sulphate all showed promise but interactions between them were considerable.

Experimental Details

In 1955 a 2^5 factorial experiment, in four replications, was carried out to test the effects on groundnuts of the following treatments:

P	Superphosphate (18 per cent. P_2O_5)	2 cwt./acre
K	Potassium sulphate (48 per cent. K_2O)	2 cwt./acre
Ca	Hydrated lime (73 per cent. CaO)	20 cwt./acre
Mg	Magnesium sulphate (16 per cent. MgO)	2 cwt./acre

The soil was lateritic with a variable gravel content which may reach 87 per cent. but the 'fine earth' had up to 77 per cent. of clay, predominantly kaolinite. There was, however, an excellent crumb structure and this was maintained throughout the year despite a rainfall of over 100 inches. The base-exchange capacity was between 4 and 7 m.e. per cent. with about 30 per cent. saturation. Three crops of upland rice had been taken previously from the experimental site, with poor yields.

At the end of the previous season the crop residues were ploughed under and subsoiling was carried out. Early in 1955 the site was ploughed; all later cultivations were done by a rigid-tine cultivator which left an excellent seed-bed. The fertilizers were broadcast on 5 May and harrowed in, the plots being planted immediately after. A local groundnut variety, Kono, a type of Long Valencia [12], was used; two kernels per stand were hand-planted 7 inches apart, in 10-inch rows. The plots were 7×4 yards, surrounded by 1 yard of unplanted discard. Sample plants were taken for analysis on 6 June and 20 July and the crop was pulled by hand between 29 August and 7 September. Fruits were removed immediately and were dried under cover with the assistance of hot-air blowers. Plant weights were not taken as there had been considerable defoliation due to infection by both *Cercospora arachadicola* and *C. personata*. The fruits from each plot were divided into groups on the basis of the number of ovular cavities and counted. Each group was then shelled, and the number and weight of kernels and the weight of shell recorded.

Chemical Analysis

The growing plants collected for analysis were rapidly washed in tap-water; the roots were removed by cutting through the hypocotyl

and discarded. The tops were then rinsed in distilled water containing a small quantity of Teepol XL. On 20 July some plants carried small fruits which were scrubbed with a nylon brush to remove adhering soil. After weighing, the tops were cut into small pieces with stainless-steel scissors and rapidly dried at 105° C. Dry ashing was carried out at a temperature of about 500° C. and the ash was taken up in hydrochloric acid. Colorimetric determinations were made of phosphorus, manganese, and iron whilst calcium and potassium were measured turbidimetrically. Magnesium was not determined. Iron was determined to discover whether a chlorosis of plants receiving superphosphate was due to iron deficiency and to serve as a check of the washing procedure, the soil being rich in iron oxides.

Results are summarized in Table 1. As expected, elements liable to 'luxury consumption' were taken up in larger quantities when added in fertilizers, e.g. potassium and manganese. Phosphorus was rapidly absorbed from the fertilizer in the early stages of growth but, by the time of fruit formation, little difference could be detected in the analysis of plants from the various treatments. It can be assumed, therefore, that the soil contains sufficient slowly available phosphorus for normal growth. Conversely, the effect of the lime was not noticed until late in the season when there was a heavy demand during fruiting. Calcium is presumably at a sub-optimal level in Njala soil.

Correlated with the rapid initial uptake of phosphorus, superphosphate was effective in increasing the dry-matter content of the plants shortly after germination but conferred no benefit later. Potassium sulphate had very little effect until flowering, when not only was there rapid uptake of potassium but also a marked increase in dry-matter content. In the field at this stage it was simple to pick out the plots which had received this fertilizer as the plants were much larger. Magnesium sulphate also caused an increase in the dry-matter content of the plants.

Although superphosphate had no effect on the total iron content it reduced the concentration of this element in the dry matter by 26 per cent., a very significant difference and possibly sufficient to account for the observed chlorosis. If so, this is a most unexpected result as the lateritic soil is rich in iron.

Harvest Results

These are given in Table 2. Results from the use of manganese sulphate have been omitted as this fertilizer caused no effect even approaching significance. No table of mean effects is given as interest lies in the interactions.

Discussion

Individually, both lime and superphosphate improved yields to a similar extent but together they produced no further increase, there being a significant negative interaction. Potassium sulphate and magnesium sulphate had no effect when used alone or in combination but in the presence of either lime or superphosphate they were highly

TABLE 1. *Mean Effect of Fertilizers on the Dry Matter and Composition of a Single Groundnut Plant*

(Increases (+) or Decreases (−) in comparison with control receiving no fertilizer)

Date	*Treatment*	*Dry matter, gm.*	*Phosphorus, gm.* $\times 10^{-6}$	*Potassium, mgm.*	*Calcium, mgm.*	*Manganese, gm.* $\times 10^{-6}$	*Iron, gm.* $\times 10^{-6}$
6 June	Superphosphate	+0·562†	+182†	+2·22	+0·52	+41·0	+45·5
	Potassium sulphate	+0·119	−12	+17·35	−0·64	+52·9	+45·0
	Hydrated lime	+0·119	−13	+6·10*	+0·71	−73·5	+10·6
	Magnanese sulphate	−0·031	+110	+0·94	−0·24	+161·6	−34·1
	Magnesium sulphate	+0·094	+70	+1·56	−0·12	+13·6	−9·4
	Least significant effect at $P = 0·05$	0·353	106	5·75	1·05	78·7	51·6
20 July	Superphosphate	+0·32	+1,020*	+10·1	+1·44	+85	+6
	Sulphate of potash	+8·10†	−373	+94·6†	+11·71†	+274	+625†
	Hydrated Lime	+2·94	−236	+48·9	+7·50?	−222	+131
	Manganese sulphate	−0·09	−45	−4·3	−2·22	+1,043	−194
	Magnesium sulphate	+4·31*	+425	+18·2	+10·00†	+399	+238
	Least significant effect at $P = 0·05$	3·84	843	38·4	7·50	530	400

* = Significant at $P = 0·05$. † = Significant at $P = 0·01$

TABLE 2. *Effect of Fertilizers on the Yield and Composition of Groundnuts*

Treatment	*Yield of fruit (lb./acre)*	*Shelling percentage*	*Number of fruit (thousands/acre)*	*Kernels per fruit*	*% Ovular cavities filled*
Control	500	57	177	1·00	40·3
Ca	830	70·5	226	1·86	75·8
K	518	41·5	231	0·58	21·4
CaK	915	64·5	281	1·50	70·8
Mg	475	47·5	218	0·63	29·1
CaMg	1,110	66·0	313	1·64	75·5
KMg	628	36·0	359	0·44	18·0
CaKMg	1,495	44·5	435	1·58	72·0
P	825	70·1	246	1·44	68·0
CaP	800	70·0	225	1·75	81·2
KP	1,160	60·0	391	1·13	50·2
CaKP	1,050	68·5	323	1·55	76·6
MgP	950	68·0	287	1·45	67·5
CaMgP	910	69·0	242	1·84	83·5
KMgP	1,140	55·0	373	1·14	50·9
CaKMgP	1,380	67·0	357	1·74	76·2

Least significant difference at $P = 0{\cdot}05$ level: 132 lb.

beneficial, the three-treatment interactions, CaKMg and PKMg, being positive and significant. The CaKMg treatment gave the highest yield in the experiment, 1,495 lb. of fruit per acre, an increase of 200 per cent. over the control. The effects of lime and superphosphate appear identical and, taking the analysis figures into account as well, it would seem that, at the level used in this experiment, the value of superphosphate lies entirely in its calcium content.

This possibility has been suggested for other localities [3, 5] but was not suspected here, for 'triple' superphosphate has been shown to be as effective as 16 per cent. superphosphate [13]. If there is an acute calcium deficiency in the soil, as there appears to be, even the small quantity in 'triple' superphosphate may be sufficient for the production of a fair crop.

The additional data in Table 2 indicate the reasons for the somewhat surprising interactions between the treatments. Lime, potassium sulphate, and magnesium sulphate were effective in increasing the number of fruits produced; their interactions were non-significant and the increases were additive. Superphosphate again acted similarly to lime; both were valuable in greatly increasing the number of kernels per fruit, whilst potassium sulphate and magnesium sulphate decreased it. This was not due to variations in the number of available ovular cavities but to a difference in the number of kernels coming to maturity, calcium-bearing fertilizers reducing the number of 'pops'.

The calcium effect was not unexpected as similar results have been obtained elsewhere [14] but under Sierra Leone conditions the full potentialities of calcium fertilizers were not realized until the potassium and magnesium available to the plant were increased. These elements were ineffective, however, until there was sufficient calcium available

to satisfy the plants' heavy demand at fruiting, although they increased plant growth and could be useful for forage crops.

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MANURING OF COTTON IN WEST PAKISTAN[1] III. EFFECT OF RATE AND KIND OF MANURING AND DATE OF SOWING ON THE YIELD OF SEED COTTON

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Summary

Experiments to study the effect of dates of sowing and manuring were conducted over a period of four years at five stations representing various varietal zones. There were two dates of sowing at each station, one normal and the other 1 month later. There were three levels of manuring, 0, 50, and 75 lb. N per acre, applied as ammonium sulphate, as farmyard manure, and as a combination of the two with an equal amount of nitrogen supplied by each. The earlier sowing gave better yields than late sowing at all stations except Wazirkot where the reverse obtained. Ammonium sulphate was a more effective source of nitrogen than farmyard manure for the earlier-sown cotton, and there were indications that worth-while responses might be obtained with dressings in excess of 75 lb. N per acre. On the lower-yielding late-sown cotton, however, farmyard manure alone, or in combination with ammonium sulphate, gave better responses than the latter alone. The yields were very markedly affected by weather conditions.

MANURING and date of sowing are known to have important effects on the yield of seed cotton. The relationship between these factors for conditions in the Northern Indus plains area of West Pakistan has not been worked out. An experiment involving different levels and sources of nitrogen, organic and inorganic, and different sowing dates was therefore conducted.

Review of Literature

Much of the published work on the manuring of cotton in the Indo-Pakistan sub-continent has been summarized by Dastur [1], Panse [2], Stewart [3], and Vaidyanathan [4]. Inorganic fertilizers containing nitrogen, phosphorus, and potassium, and organic manures such as farmyard manure, cattle dung, composts, oil cakes, green manures, &c., are reported to have been used alone and in combination. In spite of conflicting and, at times, meagre data, it can be generally concluded that nitrogen-bearing fertilizers and manures have produced increased yields of seed cotton, whereas phosphorus appears to have had no beneficial effect, and potassium has depressed yields.

Materials and Methods

The present experiment was conducted at five stations in West Pakistan, using cotton varieties L.S.S., 238F, and 124F as described in Part I

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of this series [5]. The experiment was of split-plot design: manures × dates of sowing. Besides the control (M_7) there were six manurial treatments, using 50 and 75 lb. N per acre, in the form of ammonium sulphate (M_1 and M_2) or farmyard manure (M_3 and M_4) alone, or together so that each supplied one half of the nitrogen (M_5 and M_6). Dates of sowing (D_1 and D_2) were 15 May and 15 June at Lyallpur, 15 April and 15 May at Wazirkot, 25 May and 23 June at Montgomery, and 1 June and 30 June at both Khanewal and Multan; D_1 and D_2 thus represented normal and late dates of sowing respectively, for each station. For convenience, however, they are referred to hereinafter as 'early' and 'late'. Late sowing was included to see whether normal yields of seed cotton could be obtained by manuring of the late-sown crop, late sowing sometimes being unavoidable for various reasons. The plot size was $\frac{1}{40}$ acre and there were four replications in randomized blocks. Other conditions were normal, i.e. cotton followed wheat, row-to-row distance was $2\frac{1}{2}$ feet, and five to seven 3-inch irrigations were applied, depending on the rainfall. In addition one 4-inch irrigation was applied for seed-bed preparation.

Farmyard manure was applied about a month before sowing. Ammonium sulphate was given in a single broadcast application between the rows at the preflowering stage and was followed by an irrigation.

Results and Discussion

Yearly average yields of seed cotton in maunds per acre are given in Table 1, which shows that in years when the conditions were not abnormal at a particular station, there was no consistent difference between the yields with early and late sowing, at Lyallpur, Montgomery, and Khanewal. However, under abnormal weather conditions or the incidence of pests and diseases, the yields of the late-sown crop were very adversely affected. The attacks of pests and diseases coincided with periods of high atmospheric humidity, except 'tirak' (premature opening of the bolls), which appears to be associated with low relative humidity and abnormally high temperatures during the months of September and October.

At Wazirkot the later sowing, mid May, was better in the first three years but not in the fourth. At Multan the early sowing, 1 June, was definitely better than the late sowing throughout. The year 1956–7 was highly abnormal and the yields from late-sown crops at all stations except Khanewal were very adversely affected. These observations confirm the results presented in Part II [6].

Generally, with N applications there has been an increase in the yield of seed cotton per acre of 2 to 3 maunds at Lyallpur, 2 maunds at Khanewal, and 3 maunds at Multan, with N applications at the rate of 75 lb. per acre. At Wazirkot, 50 lb. N resulted in yield increases of 3 to 5 maunds. At Montgomery the results were inconclusive.

The data in Table 1 were examined statistically by the analysis of variance, and the results are summarized in Table 2.

TABLE 1. *Yearly Average Yields of Seed Cotton in Maunds* per Acre*

	1953–4					1954–5				
Treatments†	*L*‡	*W*	*Mo*	*K*	*Mu*	*L*	*W*	*Mo*	*K*	*Mu*
D_1M_1 . .	15·96	17·92	8·13	9·56	23·57	20·10	11·02	29·56	15·13	26·40
D_1M_2 . .	18·11	17·47	11·80	9·57	20·07	25·73	10·77	33·20	15·55	29·08
D_1M_3 . .	15·88	17·41	9·83	7·82	23·85	18·56	11·10	25·02	14·86	23·20
D_1M_4 . .	18·07	16·17	10·50	10·16	24·97	19·59	7·08	25·38	17·50	24·42
D_1M_5 . .	20·72	17·35	10·08	9·83	24·97	20·72	8·73	26·82	13·14	24·71
D_1M_6 . .	18·60	16·85	9·83	10·04	25·65	24·10	9·11	31·58	13·21	26·65
D_1M_7 . .	16·58	17·93	10·80	11·30	18·80	17·89	5·00	28·93	17·28	25·15
D_2M_1 . .	18·16	21·08	2·60	9·22	19·67	19·41	11·45	26·51	17·96	14·74
D_2M_2 . .	18·23	20·05	2·67	9·66	19·90	20·79	10·52	24·53	18·83	18·86
D_2M_3 . .	17·65	19·02	3·15	10·58	15·87	16·36	9·62	25·25	17·85	16·65
D_2M_4 . .	16·95	17·43	3·88	10·09	17·57	19·24	9·88	22·83	20·16	16·88
D_2M_5 . .	18·51	19·82	2·63	8·57	17·13	17·79	9·75	24·46	19·08	16·77
D_2M_6 . .	18·99	20·15	2·43	10·19	19·90	18·76	9·66	28·20	13·39	25·60
D_2M_7 . .	17·20	17·24	2·63	9·73	18·13	15·67	8·49	26·39	18·95	16·31

	1955–6					1956–7				
Treatments†	*L*‡	*W*	*Mo*	*K*	*Mu*	*L*	*W*	*Mo*	*K*	*Mu*
D_1M_1 . .	16·48	14·47	16·21	17·00	18·90	13·27	19·61	15·65	11·79	15·68
D_1M_2 . .	17·20	15·84	13·46	15·58	21·11	14·39	19·31	17·86	13·33	10·92
D_1M_3 . .	14·82	12·58	10·52	15·78	19·71	13·77	17·58	18·33	11·38	11·12
D_1M_4 . .	15·22	12·08	12·63	15·90	21·85	11·34	16·46	15·48	13·55	10·68
D_1M_5 . .	14·88	13·69	15·11	14·85	20·17	15·04	19·28	15·29	12·38	11·59
D_1M_6 . .	16·72	14·33	16·85	13·70	19·98	13·15	17·31	16·15	13·67	12·59
D_1M_7 . .	14·60	11·94	12·67	14·28	18·94	12·54	13·99	15·12	12·36	15·10
D_2M_1 . .	9·08	18·46	7·92	9·65	13·73	4·17	16·49	2·44	2·69	1·56
D_2M_2 . .	10·18	17·08	8·42	11·62	15·02	4·37	16·86	3·17	1·96	1·95
D_2M_3 . .	9·42	16·07	8·59	13·05	15·08	5·87	15·59	4·42	2·31	2·03
D_2M_4 . .	10·02	14·14	11·88	11·62	15·39	4·17	16·54	3·42	2·78	2·09
D_2M_5 . .	11·00	15·20	12·09	12·00	12·07	3·52	16·69	3·22	1·72	1·87
D_2M_6 . .	10·68	16·16	11·60	11·22	15·33	4·04	17·73	3·57	2·19	1·59
D_2M_7 . .	9·75	12·80	7·13	9·85	15·66	3·45	13·09	2·47	2·35	2·45

* Maund = 82 lb.

† D_1 = early sown.
D_2 = late sown.
M_1 = 50 lb. N as ammonium sulphate.
M_2 = 75 lb. N as ammonium sulphate.
M_3 = 50 lb. N as farmyard manure.
M_4 = 75 lb. N as farmyard manure.
M_5 = 50 lb. N half as ammonium sulphate and half as farmyard manure.
M_6 = 75 lb. N half as ammonium sulphate and half as farmyard manure.
M_7 = no manure.

‡ L = Lyallpur; W = Wazirkot; Mo = Montgomery; K = Khanewal; Mu = Multan.

The statistical analysis shows that the results regarding date of sowing are such that it is difficult to draw any firm general conclusion. However, the effect of manuring was generally highly significant at Wazirkot and Multan, while at the other stations it was significant or highly significant for one or two years only.

In Table 3, 4-year mean yields of seed cotton are given.

The effect of date of sowing is more evident in Table 3. The level of yields in the top part of the table (treatments Nos. 1 to 7) is higher than for those in the lower part (treatments 8 to 14), for all stations except Wazirkot where the later sowing was better than the earlier.

TABLE 2. *Results of Statistical Analysis showing Least Significant Differences at 5 per cent. (*) or 1 per cent. (†) level for those effects showing these levels of significance*

Treatments	Stations	Years			
		1953–4	1954–5	1955–6	1956–7
Dates of sowing .	Lyallpur .	N.S.	N.S.	3·12*	5·44†
	Wazirkot .	N.S.	N.S.	1·56*	N.S.
	Montgomery .	1·50†	N.S.	3.27*	4·71†
	Khanewal .	N.S.	N.S.	N.S.	3·19†
	Multan .	N.S.	N.S.	3·19*	3·82†
Manures . .	Lyallpur .	N.S.	2·20†	1·68†	N.S.
	Wazirkot .	2·58†	N.S.	1·09†	2·81†
	Montgomery	N.S.	3·45†	N.S.	N.S.
	Khanewal .	N.S.	3·23*	N.S.	1·19*
	Multan .	5·03†	3·11†	N.S.	1·29†

N.S. = Not significant. * $P < 0.05$ = Significant. † $P < 0.01$ = Highly significant.

TABLE 3. *Four-year mean Yields of Seed Cotton in Maunds per Acre*

Serial no.	Treatments*	Stations				
		Lyallpur	Wazirkot	Montgomery	Khanewal	Multan
	Early sown (D_1)					
1	50 lb. N (M_1) . .	16·45	15·76	17·39	13·37	21·14
2	75 lb. N (M_2) . .	18·86	15·88	19·08	13·51	20·30
3	50 lb. N (M_3) . .	15·76	14·67	15·93	12·42	19·47
4	75 lb. N (M_4) . .	16·81	12·95	16·00	14·17	20·48
5	50 lb. N (M_5) . .	17·84	14·76	16·83	11·80	20·36
6	75 lb. N (M_6) . .	18·14	14·40	18·67	12·66	21·22
7	Control (M_7) . .	15·40	11·47	16·88	13·81	19·50
	Late sown (D_2)					
8	50 lb. N (M_1) . .	12·71	16·87	9·87	9·88	12·43
9	75 lb. N (M_2) . .	13·49	16·13	10·20	10·52	8·94
10	50 lb. N (M_3) . .	12·33	15·08	10·60	10·95	12·41
11	75 lb. N (M_4) . .	12·60	14·50	10·50	11·16	12·98
12	50 lb. N (M_5) . .	12·71	15·37	10·60	10·34	11·96
13	75 lb. N (M_6) . .	13·12	15·93	11·45	9·25	15·61
14	Control (M_7) . .	11·52	12·91	9·66	10·22	13·15

* For key to manurial treatments M_1–M_7 see Table 1.

Farmyard manure used alone gave inferior results in comparison with ammonium sulphate alone, or when used together with ammonium sulphate. Furthermore, ammonium sulphate alone generally gave better yields than when used in combination with farmyard manure, for the same quantity of N. There were no marked or consistent differences between the yields at the two different rates of manuring, except in some cases at Lyallpur and Montgomery. Since in farmyard manure biological changes precede the availability of nitrogen to plants and thus the availability of organic nitrogen is spread over a longer period, all its nitrogen may not become available to the crop to which it is applied, whereas the quick

action of inorganic nitrogen on plants ordinarily leaves no residue after the crop to which it is applied.

The lower part of Table 3 shows that by the use of 75 lb. N, half as farmyard manure and half as ammonium sulphate (M_6), increases in yield of seed cotton, varying from 1·6 to 3 maunds per acre, were obtained from cotton sown late (D_2), except at Khanewal.

The treatment consisting of early sowing (D_1) and 75 lb. N per acre as ammonium sulphate (M_2) was generally the best and resulted in average yield increases of 3·46, 4·41, 2·20, and 0·80 maunds of seed cotton per acre at Lyallpur, Wazirkot, Montgomery, and Multan, respectively, but at Khanewal the mean yield showed no response to 50 or 75 lb. N. At Wazirkot, with the later sowing (D_2), and 50 lb. N, there was a yield increase of 3·96 maunds per acre.

Table 4 shows the general means for each treatment combination, for all five stations together.

TABLE 4. *Effect of Individual Factors on the General Mean Yield of Seed Cotton in Maunds per acre*

Serial no.	Treatments (*for Key see Table 1*) *A.S. = Ammonium sulphate F.Y.M. = Farmyard manure*		*General means* M_1 to M_7	*General means* D_1 and D_2	*Mean yield increases from manuring* Response from 50 lb. N	Response from 75 lb. N	Difference between 75 and 50 lb. responses
1	$D_1 \times 50$ lb. N(M_1)	A.S.	16·80	D_1 16·40	1·39		
2	$D_1 \times 75$ lb. N(M_2)	A.S.	17·52			2·11	+0·72
3	$D_1 \times 50$ lb. N(M_3)	F.Y.M.	15·67		0·26		
4	$D_1 \times 75$ lb. N(M_4)	F.Y.M.	16·08			0·67	+0·41
5	$D_1 \times 50$ lb. N(M_5)	A.S. + F.Y.M.	16·32		0·91		
6	$D_1 \times 50$ lb. N(M_6)	A.S. + F.Y.M.	17·02			1·61	+0·70
7	D_1 Control (M_7)	No N	15·41		Mean 0·85	1·46	+0·61
8	$D_2 \times 50$ lb. N(M_1)	A.S.	12·35	D_2 12·36	0·86		
9	$D_2 \times 75$ lb. N(M_2)	A.S.	11·81			0·32	−0·54
10	$D_2 \times 50$ lb. N(M_3)	F.Y.M.	12·67		1·18		
11	$D_2 \times 75$ lb. N(M_4)	F.Y.M.	12·35			0·86	−0·32
12	$D_2 \times 50$ lb. N(M_5)	A.S. + F.Y.M.	12·18		0·69		
13	$D_2 \times 75$ lb. N(M_6)	A.S. + F.Y.M.	13·67			1·18	+0·49
14	D_2 Control (M_7)	No N	11·49		Mean 0·90	0·78	−0·12
	Overall general mean		14·38		0·88	1·12	+0·24

The second and third columns, Table 4, show that the general effect of late sowing was a reduction of 4 maunds in yield per acre, and that

this was on the whole irrespective of manuring. The unmanured crop (M_7), when sown late, yielded 3·92 maunds less than that sown early, whilst the average yield for all the manured crops (M_1–M_6 incl.) when sown late was 4·23 maunds less than that sown early.

For most of the individual manurial treatments (M_1, M_4, M_5, M_6), the difference between the yields of early- and late-sown crops was within the range of 3·7 to 4·5 maunds, but for 75 lb. N as ammonium sulphate (M_2) it was 5·7 maunds, and for 50 lb. N as farmyard manure (M_3) it was only 3·0 maunds. There is thus an indication of an interaction between date of sowing and manuring, in the sense that the inferiority of late sowing was less with farmyard manure than with ammonium sulphate.

This indication is supported by the figures in the right-hand three columns of Table 4. The overall general mean responses to 50 and 75 lb. N per acre were 0·88 and 1·12 maunds of seed cotton, but these figures are not very helpful, since they average the different levels of response of the early- and late-sown crops, and also the differences in response to the different kinds of manuring.

For the early-sown crop, the responses to 50 and 75 lb. N. as ammonium sulphate were 1·4 and 2·1 maunds of seed cotton—a linear relation of response to amount of nitrogen, with the indication that an even higher nitrogen dressing could produce a further response. Farmyard manure was much less effective, but the higher dressing, although only half as big again as the lower, gave 1½ times the response, with the 50 : 50 combination intermediate. For early-sown cotton, therefore, there was a marked superiority in effectiveness of the quick-acting inorganic nitrogen of ammonium sulphate over the slower-acting organic nitrogen in farmyard manure.

For the late-sown cotton, on the other hand, although the general level of response to 50 lb. of nitrogen was about the same as for the early-sown, the farmyard manure was *more* effective than ammonium sulphate, while at the 75 lb. nitrogen level, although farmyard manure was still superior to ammonium sulphate, the 50 : 50 combination was even better than either alone. There was thus a marked interaction between time of sowing and the relative effectiveness of ammonium sulphate and farmyard manure supplying the same amount of nitrogen.

It may therefore be concluded tentatively that, at the lower yield level resulting from late sowing, farmyard manure alone, or together with ammonium sulphate, is a more effective fertilizer than the latter by itself.

Approximate estimates may be made of the profitability of manuring cotton in the conditions under which these experiments were carried out, and on the basis of the responses here recorded, at prevailing prices of ammonium sulphate (subsidized price 8 rupees[1] a maund), farmyard manure (5 rupees a ton, containing 10 lb. N) and seed cotton (30 rupees a maund). (The costs of ammonium sulphate (at the subsidized price) and farmyard manure, for equal amounts of nitrogen, are about the same.)

On the above basis, for early-sown cotton, the use of 50 lb. N as ammonium sulphate, with a response of 1·4 maunds of seed-cotton per acre

[1] 1 rupee = 1*s.* 6*d.*

would result in a profit of 17 rupees, while at the 75 lb. N rate, and a response of 2·1 maunds, the profit would increase to 26 rupees. On the other hand, the response obtained from farmyard manure containing the same amounts of nitrogen (0·26 and 0·67 maunds for 50 and 75 lb. N respectively) would both result in financial loss. Using the 50 : 50 combination, with the responses of 0·91 and 1·61 maunds respectively at the two rates of N, would have given profits of 3 and 11 rupees respectively.

With late-sown cotton, on the same bases as above, the use of 50 lb. N in the 50 : 50 combination would give a profit of 10 rupees.

It should be noted that the above figures make no allowance for the extra cost of carting and incorporating the farmyard manure, which would appreciably reduce the margin of profit.

Table 1 shows how the yields varied from locality to locality and from year to year. This was due not merely to soil and varietal differences, but also to differences in weather conditions. This is shown, for example, by the yields at Khanewal and Multan where the soils on the experimental areas were almost similar (see Table 1, Part I [5]) and where similar agronomic practices were followed and the same variety was grown; but nevertheless there were marked differences in the yields (Table 1). A similar situation was noticeable in Table 2, Part I [5], and in the annual yields in the experiment reported in Part II [6]. Khanewal and Multan are only 31 miles apart. This suggests that relatively small differences in weather conditions might exert a marked influence on the yield of seed cotton.

The operative factors in weather are the maximum and minimum temperatures and their duration, rainfall, humidity, and wind velocity. The available data with respect to these factors for the above two stations are presented in Table 5.

TABLE 5. *Maximum and Minimum Temperatures, Rainfall, and Humidity, from May to December, at Multan and Khanewal*

Years (*May to Dec. incl.*)	*Multan*				*Khanewal*			
	Temperature, ° F.		*Total rainfall, inches*	*Relative Humidity %*	*Temperature, ° F.*		*Total rainfall, inches*	*Relative humidity, %*
	Max.	*Min.*			*Max.*	*Min.*		
1953	96·5	76·1	8·42	64·8	97·2	73·4	4·57	..
1954	97·1	70·7	0·89	60·0	97·7	73·4	4·72	..
1955	94·6	69·7	8·97	67·1	94·8	73·9	6·92	..
1956	95·1	70·0	4·73	64·0	93·7	72·4	3·08	..
Mean	95·8	71·6	5·75	63·9	95·8	73·3	4·82	..

Table 5 shows that at Multan the minimum temperature was lower by 2 to 3 degrees except in 1953, while rainfall was higher by from about 2 to 4 inches except in 1954. Unfortunately, data for humidity at Khanewal are lacking; but the presumption that humidity at Multan is higher than that at Khanewal is allowable, having regard to the higher rainfall at Multan and its closer proximity to the river. Further examination of the monthly rainfall records from August to October, the critical

period for the setting of flowers, shows that though the maximum temperatures at both the localities were similar the minimum temperatures during this period were persistently lower at Multan. Higher day temperatures, lower night minima, and higher humidity are the conditions which favour the cotton plant.

The cotton plant produces two types of branches, vegetative and fruiting. The physiological response which finds its expression in the type of branches produced is influenced by the temperature and length of day. Dastur [1] observed that the lower temperatures were more conducive to the development of vegetative branches. He also pointed out that the reproductive phases of the cotton crop are physiologically unbalanced and in the case of the Punjab-American cottons such a condition results in greater vegetative growth and less boll formation. Moreover, the rate of absorption of water by the roots increases with increase in temperature up to an optimum temperature beyond which it falls again. It is thus clear that temperature will not only determine the type of branches produced but will also affect the rate of absorption of water by roots, which will in turn influence the physiological activity of the cotton plant. Lower night temperatures and humidity appear to affect the setting of flower and consequently influence the yields.

The cotton plant is thus very sensitive to weather conditions, but also reacts to agronomic factors and the physical, chemical, and biological conditions of the soil. Varietal reaction is also a factor which influences yield. Any of these factors which does not synchronize with the physiological requirements of the cotton plant will adversely affect the yields. In the conditions under which these experiments were conducted, the operative factors could not all be in unison with the requirements of the cotton plant and this resulted in lower yields and reduction in the response to fertilizer application. However, whenever good conditions existed the plant reacted favourably to its environment and consequently to the fertilizers, which was reflected in increased yields, as illustrated by the yearly yields of seed cotton in Table 1. In some cases responses to manuring as high as 8 maunds per acre have been obtained. Thus it is very difficult to predict whether manuring of cotton will be profitable, and if so whether it will be attractive enough to induce the grower to apply fertilizers; to obtain the best response to fertilizers demands the synchronization of several variables at their optima to suit the physiological requirements of the cotton plant, and this seldom occurs under field conditions.

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STUDIES IN EGYPTIAN BALADI GOATS
I. FREQUENCY OF MULTIPLE BIRTHS AND SEX RATES

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WITH PLATE I

Summary

This investigation deals with different factors, genetical and environmental, that influence the frequency of multiple births in Egyptian Baladi goats. It was carried out on 288 does reared on the University Farm during the years 1943–57.

The following results have been obtained:

1. Heritability and repeatability estimates for multiple births were 28·8 and 24·6 per cent. respectively.
2. Kidding percentage over the whole period studied was between 150 and 244 per cent.
3. Sequence of kidding, age, and weight of dams affect the incidence of multiple births, which increased gradually from the first sequence of kidding to the fifth, after which it decreased.
4. Type of birth of dams may influence the frequency of multiple births; the highest percentage of kidding was achieved from dams that were born as multiples.
5. Seasons and years influenced significantly the occurrence of multiple births.
6. Sex-ratio was 56 per cent. males to 44 per cent. females.

DOBZHANSKY [1] has stated that goats could be classified into four distinct groups, viz.

1. The common goats of Europe.
2. The Nubian goats, found in Nubia, upper Egypt, and Abyssinia.
3. The Angora goats as originated in Turkey.
4. The Kashmir goats.

Goats in Egypt

The Ancient Egyptians seem to have possessed large flocks of goats and to have given great attention to their breeding, probably for their milk production. A study of the skulls [2] of the Ancient Egyptian goats indicates that the only domestic type found in Egypt, from the first dynasty onwards, was a twisted-horned species resembling *Capra prisca*, a species now found in southern and south-eastern Europe. A dwarf type of goat existed in Egypt only in pre-historic times.

At present, the native Egyptian or Baladi goat is a small type; the whole body is covered with long straight hair, smoother and shorter on neck and head. The hair varies much in colour, from one animal to another, from black to white, whilst some are spotted and others brown or reddish brown. Some have horns, which are small and curl back on the head, but others are hornless. Ears differ in position and size. The outline of the face is straight, and the head, which is beardless, is long and possesses two tassels. The udder is long and bagged, with two unshapely teats (Figs. 1, 2, 3, Plate I).

One of the few experimental farms in Egypt which keeps goats for breeding purposes is the Alexandria University Farm, stocking a large

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FIGS. 1 and 2. Horned and polled Baladi goats; ears; shape of the head and tassells

FIG. 3. Udder of Baladi goat

flock of Baladi goats and Angora goats as pure lines, as well as their crosses.

The total number of goats in the Mediterranean countries has been discussed by Maule [3] who reported that there were about three-quarters of a million goats in Egypt in 1949. The number of the Baladi goats in Egypt for the years 1941–55, from the statistical records of the Egyptian Ministries of Finance and Agriculture [4, 5], were almost constant about this figure.

Figure 4 indicates that the largest number of goats is found in Suhag and Minia provinces of Upper Egypt, while they are least numerous in the Delta (Lower Egypt). Such differences between Lower and Upper Egypt could be attributed either to scarcity of animal feeds during a great part of the year, or to neglect by the big landowners. Eighty-six per cent. of the total number of goats are distributed throughout the Nile Valley, 1 per cent. around big cities such as Cairo and Alexandria, and 13 per cent. in the various oases scattered throughout the western and eastern deserts.

Goats as Dairy Animals

Eastern Mediterranean countries have been known for many centuries as an area for breeding goats on a large scale. These animals are very useful because they do not cost much to be maintained, and also on account of their high efficiency in utilizing food to produce cheap milk and meat. In a country such as Egypt, where most of the farmers are agricultural labourers, keeping a good dairy goat is of great help to provide such people with cheaper meat, milk, and hair. Therefore, the creation of an efficient dairy goat adaptable to Egyptian conditions deserves consideration, and would affect the standard of living for those who cannot afford to keep a dairy cow.

Available data demonstrate that the native goats are of low productivity for either milk or meat. Steps should therefore be taken for their genetic improvement, either by selection, or by up-grading with standard foreign breeds.

Selection should be based on the most outstanding individuals among the native goats, both bucks and does, without introducing any foreign blood. Since Baladi goats are a type rather than a breed, there must be a considerable amount of genetic variation in various characters, and much improvement by selection for a chosen trait should be obtainable, given good management and environmental conditions.

Up-grading should be carried out with the standard foreign breeds such as Anglo-Nubian for the improvement of milk production, or Angora for hair improvement.

No previous work has been done on the Egyptian Baladi goats and it is the intention of the department to study their various qualitative and quantitative characters, as well as the different genetical and environmental agencies that may influence the expression of the various characters in relation to meat and milk production, and fertility. It is also intended to study the pure breeds of Angora and Anglo-Nubian goats under local conditions as well as their crosses with the Baladi goats.

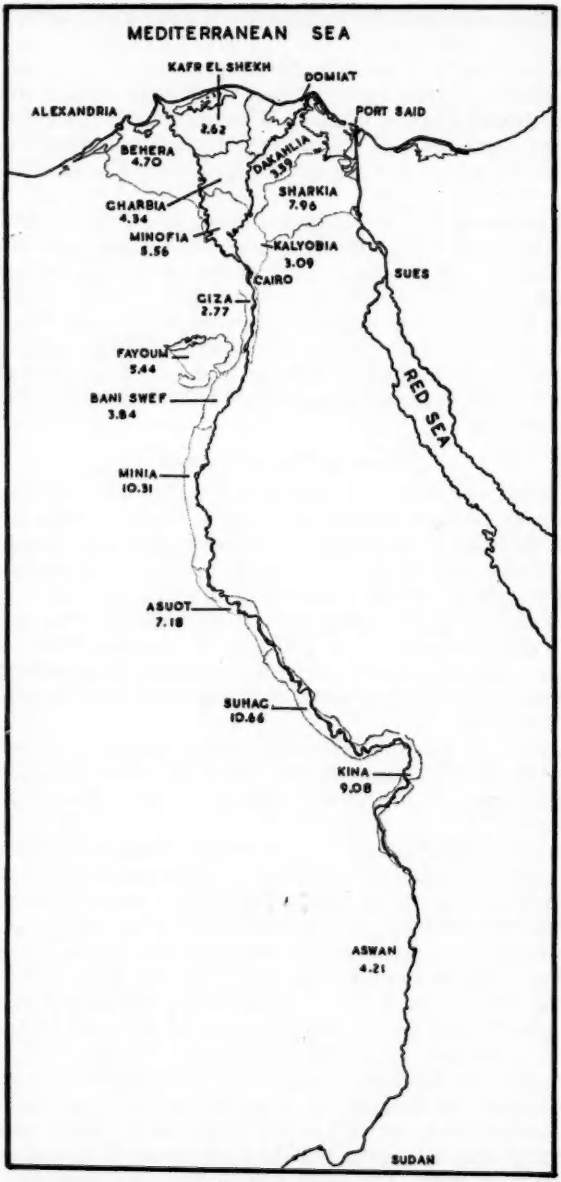

FIG. 4. Distribution of goats in Egypt in different Provinces, expressed as percentages of the total number of goats in Egypt.

Studies on Frequency of Multiple Births, and Sex Ratio

Prolificacy in goats depends greatly on the influence of various environmental agencies as well as on genetic variation. Estimates of the effects of such factors are needed, particularly for experiments aimed at increasing the productive ability of the flock.

Frequency of multiple births is one of the most important traits for many breeds of livestock, such as goats, sheep, pigs, and rabbits. In goats the number of kids born per doe as well as the numbers that survive to maturity are of great economic importance for meat production.

Until now no attempts have been made with Egyptian Baladi goats to study the various characters and to sort out genetic from non-genetic influence. The purpose of the present investigation is to study the genetical and environmental agencies that may influence multiple births of Baladi goats in Egypt.

Source of Data

Data for the present study were collected from the records of goats kept on the University Farm, for the last fifteen years (1943–57), which included 288 births. Most of the kiddings occurred during the period from December to May.

During winter (from October to June) the goats were fed mainly on berseem (*Trifolium alexandrinum*). During the rest of the year they were fed on green sweet sorghum or other green fodders, supplemented with 0·5 kg. of concentrates (1 part cotton seed cake+1 part rice bran) per adult.

Results

Two parameters are involved in the present investigation of the different agencies that affect multiple births, viz. (*a*) genetic, which includes heritability and repeatability; and (*b*) environmental, which includes age of dam and sequence of kidding, type of birth of dam, time of mating, season and year.

Genetic Parameters

It is believed that there are marked differences between various breeds of goats, in their ability to produce multiple births. Though no work has yet been reported on that subject, the authors' observations indicate that such differences may exist between Egyptian Baladi goats and Angora goats reared under similar environmental conditions, and that multiple births are more frequent in Baladi than in Angora goats. Table 1 shows the frequency of multiple births in the Egyptian Baladi goats in the data examined.

Differences between the occurrence of single or multiple births in the Egyptian Baladi goats are probably genetic since, in the present data, one female which was born as a triplet produced 57 living kids: one single, 16 sets of twins and 8 sets of triplets, in 13 years. Her descendants have shown a similar prolificacy. One of her progeny gave 26 living kids: 2 singles, 1 set of twins, 6 sets of triplets, and 1 set of quadruplets in 7 years.

TABLE 1. *Frequency of Multiple Births in the Egyptian Baladi Goats, as percentage of the Total Number of Births*

	Distribution of single and multiple births			
No. of births	*Single*	*Twins*	*Triplets*	*Quads*
288	25·6	46·3	24·6	3·6

One could measure the ability of the doe to produce multiple births at different sequences by the repeatability and the genetic variance, i.e. the ability to transmit such a character to the offspring, as shown in Table 2. Repeatability is measured as correlation coefficients between the first three sequences of kidding from the same doe; while heritability is measured as the regression coefficients of offspring type of birth on that of the dam. The results presented in Table 2 (though the total number used in both estimates is small) indicate that does producing a high percentage of multiple births at first kidding show significantly the same trend at subsequent kiddings. Table 2 also shows that multiple births in goats is a character of highly genetic variance which is due to the effects of additive genes.

TABLE 2. *Repeatability and Heritability Estimates for Multiple Births*

Repeatability %		*Heritability* %	
Number	*Estimates*	*Number*	*Estimates*
93	28·8±0.9	82	24·6±1.2

One may conclude from these results that selection for increasing the incidence of multiple births in Egyptian Baladi goats could be practised on safer grounds. Thus a rise in the average number of kids born could be achieved by culling those that show poor ability to produce multiple births.

Environmental Parameters

The most important factors that affect the response to selection are environmental conditions. Response to selection could be achieved on the basis of high genetic variance for the character concerned together with stability of environmental agencies. A study of the various environmental conditions that influence multiple births in goats is thus of great importance. These agencies are as follows:

Age of dam and sequence of kidding. Analysis of the records in the present study indicates that frequency of multiple births in Egyptian Baladi goats increased with the increase of the dam's age (Table 3). Percentage of multiple births increased up to the fifth sequence of kidding (about 4 years old) after which it decreased.

Single births were about 15 per cent. of the total births, while the

frequency of twinning was rather high (47 per cent.). Percentage of triplets was intermediate between the above two values, being 30 per cent., while quadruplets showed the lowest percentage.

TABLE 3. *Frequency of Multiple Births in Relation to Age (Years) and Weight (Kilograms) of Dams, and Sequence of Kidding*

Sequence of kidding	*No. of dams*	*Dam's weight*	*Dam's age*	*Frequency of multiple births %*				*Kidding %*
				Singles	*Twins*	*Triplets*	*Quads*	
1st	43	21·4±1·7	1·6±0·1	27·9	58·1	14·0	..	186
2nd	35	27·1±1·8	2·3±0·1	14·3	54·3	31·4	..	217
3rd	36	31·2±1·7	3·0±0·1	15·4	38·5	26·9	19·3	250
4th	27	32·8±2·0	3·7±0·3	17·7	35·3	29·4	17·7	247
5th	21	33·3±1·8	4·1±0·2	..	45·5	54·6	..	255
6th and over	31	34·8±2·5	6·5±0·4	18·8	53·1	28·2	..	209
Total or averages	193	30·0±2·1	3·6±0·2	15·7	47·5	30·7	6·2	227

Table 4 indicates that dam's weight (measured after kidding) may have an effect on the occurrence of multiple births, though the differences were not significant.

TABLE 4. *Dam's Weight (After Kidding), at Different Sequences of Kidding, in Relation to Offspring Type of Birth*

Sequence of kidding	*Dam's weight*			
	Singles	*Twins*	*Triplets*	*Quads*
1st	20·8±1·3	21·6±1·0	21·8±1·8	..
2nd	23·0±1·7	26·4±1·8	20·3±1·9	..
3rd	31·3±2·7	29·0±1·0	31·0±1·6	35·8±2·8
4th	32·3±1·6	31·0±1·2	36·3±2·2	30·3±2·1
5th	32·3±1·8	31·0±1·1	36·3±2·5	30·3±1·1
6th & over	..	36·0±2·0	29·7±1·6	..
Total and averages	28·0+2·0	29·1+1·5	30·9+2·1	32·2+2·0

Average weights of dams at different sequences of kidding (Table 4) show that maturity in weight was attained at about the third year of age. Moreover, the heaviest dam gave the largest number of kids per birth. These results agree fairly well with those reported on sheep by Johansson and Hansson [6] and Karam [7].

Type of birth of dam. Table 5 shows the percentages of single and multiple births for different females according to their type of birth, and indicates that type of birth of dam, regardless of the effects of sire, may have had an influence on the number of kids born. It also shows that twin-born dams seemed to be more prolific than dams from other types of birth. These results are similar to those reported on sheep by Desai and Winters [8], Ragab and Asker [9], and Karam [7], who found that twin-born ewes were more fertile than single-born ones.

TABLE 5. *Occurrence of Multiple Births in Relation to Dam's Type of Birth*

Dam's type of birth	*No. of dams*	*No. of births*	*Multiple births %*				*Kidding %*
			Singles	*Twins*	*Triplets*	*Quads*	
Single . .	15	41	31·7	48·8	19·5	..	188
Twin . .	20	80	17·5	41·3	32·5	8·8	232
Triplet . .	16	43	18·6	65·1	14·0	2·3	200
Quad . .	10	17	23·5	47·0	17·7	11·8	218
Total or averages .	61	181	22·8	50·6	20·9	5·7	209

From these results, one may conclude that type of birth of dam should be taken into consideration in selection to increase the incidence of multiple births in goats. Dams born as multiples should be selected and the full records of the does' ancestors should be carefully examined. Smirnov [10], working on the Romanov sheep, stated that the most prolific sheep in the U.S.S.R. were those from ewes which produced only 5 per cent. singles and 90 per cent. twins and triplets. Lopyrin [11], Marshall and Potts [12], and Nikoljskii [13], working on various breeds of sheep, arrived at the same conclusions.

TABLE 6. *Frequency of Multiple Births According to Season of Mating*

Season of mating	*No. of dams*	*Frequency of multiple births %*				*Kidding %*
		Singles	*Twins*	*Triplets*	*Quads*	
Winter .	22	21·2	21·2	21·2	3·0	139
Spring .	70	24·3	54·1	16·1	5·5	203
Summer .	87	24·5	52·8	20·5	2·2	201
Autumn .	109	26·2	43·5	29·7	0·6	194

Time of mating. Table 6 shows time of mating in relation to season, and indicates that females mated in spring time tended to be more fertile, and to have higher percentages of twins and quadruplets, than those bred during the other seasons, the lowest percentages being given by winter breeding.

These results may be explained by the availability of green fodders and also the mild weather during the spring season.

For sheep, Marshall and Potts [12] stated that 'It is a common observation that the twin lambs in a flock are produced chiefly in the early part of the lambing season'. They explained their results on the basis that: (*a*) good conditions affect the ewes so that they come on heat and therefore to lambing first; and (*b*) feeds are more nutritive in the early months of the season, thus favouring the production of more than one ovum by the ewes at that time.

Effects of years. Table 7 shows the frequency of multiple births and kidding percentages for various dams each year from 1943 to 1957.

These data show that kidding percentages varied significantly from

year to year, between about 150 and 245 per cent. Such differences could be attributed to changes in feeding levels, and in some uncontrollable environmental factors, from year to year. Similar results have been reported on sheep [7, 8, 9, 12]. Table 7 also shows a trend for an increase of kidding percentages during the later years which could be attributed to selection for the more prolific individuals.

TABLE 7. *Effects of Year on Multiple Births and Kidding Percentages*

Year	No. of dams	Frequency of multiple births %				Kidding %
		Singles	Twins	Triplets	Quads	
1943	10	25·0	50·0	25·0	..	200
1944	16	56·3	37·5	6·3	..	150
1945	16	37·5	43·8	18·8	..	181
1946	8	25·0	62·5	12·5	..	188
1947	5	..	100.0	..	..	200
1948	5	..	80·0	20·0	..	220
1949	6	16·7	66·7	16·7	..	200
1950	6	33·3	66·7	..	..	167
1951	13	15·4	61·5	23·1	..	208
1952	18	22·2	33·3	22·2	22·2	244
1953	21	19·1	52·4	28·6	..	210
1954	20	35·0	30·0	30·0	5·0	205
1955	44	22·7	36·4	38·6	2·3	220
1956	39	18·0	64·1	12·8	5·1	205
1957	57	22·8	43·9	29·8	3·5	214
Total or averages	284	23·3	55·2	19·0	2·6	201

Sex-ratio

Out of 564 kids available for the calculation of sex-ratio, 315 were males or 56 per cent., to 249 females or 44 per cent., i.e. 126 males to 100 females. These results agree with those reported by Addington and Cunningham [14] on Mexican goats, but are contrary to those reported on sheep [7] where the proportion of males was less than that of females.

The present results indicate that type of birth had no effect on sex-ratio; males were always more numerous than females, in single-born kids as well as among multiples.

Discussion and Conclusions

The earlier investigations on sheep show clearly that a number of genetical and environmental factors have profound effects on the frequency of multiple births. Such a character has not previously been studied in goats.

Multiple births in goats are important in meat production. It is therefore of importance to increase the incidence of such a trait through the control of environmental agencies and by improving the genetic constitution of the animal. The differences in environmental agencies that

influence the character must be diminished as far as possible before one can expect much genetical improvement to be attained by selection.

Estimates of heritability, i.e. genetic variance, for multiple births in the Egyptian Baladi goats indicate that 25 per cent. of the total variance is due mainly to the effects of additive genes. Such a trait could therefore be improved by selection on the assumption that environmental agencies are constant. If selection is effective, as expected, dams with higher frequency of multiple births are able to show such character at every parturition, as indicated by the repeatability estimates. Such an expression should be transmitted from generation to generation.

The present investigation indicates that there are many factors, other than genotype, that could influence the incidence of multiple births in the Egyptian Baladi goats, viz. age and dam's weight, sequence of kidding, type of birth of dam, season and year.

Practical applications. From the present investigation it may be concluded that much improvement in multiple births may result if the following principles are observed:

(*a*) Selection in goats should be based on actual performance of the doe as well as her pedigree record.

(*b*) Selection should be carried out on dams born as multiples and having the ability to mature early in weight, i.e. at about 3 years of age, with a high degree of fertility.

(*c*) The most favourable season should be chosen for both parturition and rearing the kids.

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